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The Journal of Bone and Joint Surgery

STIMULATION OF HEALING IN NON-HEALING WOUNDS

BY ALLANTOIN OCCURRING IN MAGGOT SECRETIONS AND OF WIDE BIOLOGICAL DISTRIBUTION *

BY WILLIAM ROBINSON, PH.D., WASHINGTON, D. C.

The remarkable success of the Baer maggot treatment [1, 2] of chronic suppurative infections has, from the outset, aroused an interest as to how the beneficial effects of maggots are produced. Among the characteristics of this treatment are rapidity of healing and growth of healthy granulation tissue. Maggots have already been found to aid indirectly in the healing process by the effective manner in which they remove necrotic tissue and reduce the infection of the wound [2, 3, 4, 7, 8, 11]. The unusual progress of healing, however, sometimes in stubborn cases of long standing, has indicated that in addition maggots may secrete something into the wound which directly stimulates the healing process. This theory has been expressed frequently in the literature [9] published on the maggot treatment.

An investigation has, accordingly, been made to determine if maggot secretions have such properties; and it has been found that maggots do secrete into the wound a definite substance which stimulates the growth of vascular granulations, cleanses the wound, and puts it in a healthy, healing condition. This material is also such that it can be obtained readily from sources other than maggot excretions.

No organism but man does anything primarily to benefit another unrelated organism. If any benefit occurs (in this case wound healing) it must be the result of a secondary or even involuntary act. This would include the excretion of faecal and urinary materials and, as these excretions are very conspicuous with maggots, a study of them was attempted first. Considering the complexity of such material, an enormous amount of experimentation would ordinarily be necessary to isolate and identify any constituent of the excretions having therapeutic properties.

* Contribution from the Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Washington, D. C.

Certain encouraging results were obtained early in the search, however, through a correlation of the following facts:

1. Many statements appear in the literature indicating that wound healing is stimulated by the application of macerated embryonic tissues or of embryonic juices.

2. A striking thing about the experiments described is that the embryos used were taken from organisms which typically possess a well developed allantois.

3. The characteristic substance in the allantoic fluid is allantoin.

4. Maggots in some way promote an increased rate of healing.

5. Arthropods, like most other animals, excrete their end product of purine metabolism largely as allantoin; maggots, therefore, probably excrete allantoin.

6. The production of allantoin through the disintegration of uric acid is said to be accelerated in an alkaline medium.

7. The intestines of maggots (through which the urinary excretions pass) have an alkaline reaction [5] sometimes as high as pH 8.2, and the wound becomes noticeably alkaline when maggots are used.

While other substances could obviously be concerned also in the healing effects obtained, the indications were that allantoin might be an important factor. No mention of the therapeutic value of this substance could be found, however, in any of the standard works on pharmacology, physiology, or pathology, or in the United States or British Pharmacopeia. As this article was being prepared for publication a single reference was found in Merck's Index, as mentioned later.

Specimens of both sterile and non-sterile maggot excretions were obtained in quantities of about ten cubic centimeters each and were found * to contain allantoin. These determinations were confirmed * by crystallographic examination. The effect of allantoin upon chronic non-healing wounds was next cautiously tested. Fortunately allantoin can be obtained commercially, and a supply was purchased. As the amount of this substance in maggot secretions is necessarily low, and is further diluted with the serous discharge from the wound, a weak solution was used. It was applied daily on wet gauze dressings. The methods of preparation and application are described later.

The cases in which the allantoin treatment was given were those of chronic non-healing wounds with oedematous, indolent tissues lining the wounds, poor in circulation, and discharging pus. These included cases of chronic ulcers, of failure to heal after extensive burns, also of wounds in which suppuration had already been considerably reduced, but with little granulation. Treatments were begun in August 1934 at the Gallinger Municipal Hospital, Washington, D. C., in cooperation with Dr. B. Golden, and later at Mount Alto Hospital, Washington, D. C., with Dr. W. P. Sherlock. This investigation was extended to the Hos-

* Through the courtesy of Dr. E. P. Clark and Dr. G. L. Keenan, of the United States Department of Agriculture.

pital for Joint Diseases, New York, N. Y., through the courtesy of Dr. J. Buchman. After the first few treatments, small areas of shining, pinkish granulation tissue could be seen growing in the wound, followed later by a general development of granulation. The new tissue bled easily and its appearance resembled healthy tissue. In soft-tissue wounds, the allantoin treatment was found to be very effective in cleansing the wound and producing healthy granulations. In cases of osteomyelitis, the rate of healing was not always found to be so rapid as when maggots were used initially. There is no doubt that living maggots play a definite rôle and are especially valuable in deep-seated infections, since they not only secrete allantoin, but also remove detritus and reduce the infection. It is not claimed that in such cases allantoin will entirely replace maggots.

Allantoin is bland, stable, and harmless. It has no odor and is non-staining. It is also quite inexpensive; a daily application of about 75 cubic centimeters of solution to a wound of moderate size costs approximately five cents. In preparing it for use, a satisfactory method is to heat a flask of sterile water to near the boiling point; then add the allantoin and gently heat without boiling until the crystals are dissolved. This should be done with reasonable aseptic precautions, as the solution cannot be autoclaved or boiled without a resultant chemical change. The strength of solution used in the present tests was at the rate of 2.5 grams of allantoin to 500 cubic centimeters of water, which is close to the saturation point. The solution was made up in quantities sufficient for about one week's use. It should not be chilled in a refrigerator, as the allantoin will easily crystallize. It is better kept out in the laboratory, but away from excessive sunlight.

The application of allantoin appears to stimulate a local, rather than a generalized, granulation. This is fortunate, as the extent of new growth can be controlled. In a deep wound, where it is necessary to promote healing from the bottom upward and to restrict lateral growth, this can be done by applying the solution in a small packing to the base of the wound and covering the sides very lightly with vaselin. Where general granulation is required, the wound should be loosely filled with gauze dressings well soaked with solution. Some of the solution might also be poured into the wound. A wet pack is then laid on top to retard drying and is covered with one or two dry packs which are fastened down with adhesive plaster. The gauze packing should be placed lightly in the wound to prevent adherence to the tissue. This treatment is painless, easily given, and requires but little time. Dressings should be renewed before they become dry. No chemicals should be used in the wound during the allantoin treatment; before the initial treatment, the wound should be well washed with sterile water. This should be preceded, of course, by the usual type of thorough débridement where necessary. While the solution will penetrate a thin pellicle over the tissue, it is, of course, better to bring it into direct contact with the living tissue.

This paper is a preliminary report, presented in the hope of interesting

others in this treatment, and does not include a discussion of case histories. The tests are being continued with other concentrations of allantoin, together with combinations of other substances occurring naturally in maggot excretions.

Allantoin is the principal terminal product of purine metabolism in animals below man and the manlike apes, and it results from the oxidation of uric acid through the action of uricase. It is also widely distributed among plants. References to its composition and derivation are numerous in works on physiological chemistry. It is regarded as an excretory material, resulting from the metabolism of the cell nucleus. In its new rôle, as a stimulator of tissue growth where development is inactive, the indications are that allantoin and possibly some of its related substances are more than waste products. They might be normally used in the nuclear structure of the cell.

Corroboration of the healing effects of allantoin was obtained through the finding of an article written in England twenty-three years ago by Macalister [6] on the therapeutic value of this substance. Merck's Index has also been found to contain an item on allantoin; although no reference is given, its source is evidently Macalister's report, as the information given is similar. Macalister found allantoin conspicuously present in the roots of comfrey, a plant formerly highly regarded by the peasantry of Europe for its healing properties. He also tried pure allantoin solution in the treatment of chronic ulcers and obtained healing effects with rapid granulations. The wounds thus treated appeared afterward to remain in good condition. He and his associates experimented to the extent of using allantoin internally in the treatment of gastric and duodenal ulcers, with success. To Macalister the writer willingly yields priority in the discovery of the therapeutic value of this material. That author also mentioned that metabolic substances might be used in cell construction. This question was later touched upon by Rose [10] who suggested that there "is the possibility of the reutilization of the purines liberated in catabolism. We are in the habit of thinking of these purines as being transformed into uric acid and with more or less promptness eliminated."

It is hoped that extensive trials of the allantoin treatment will be made and that improved methods of applying it will be described.

CONCLUSIONS

Allantoin, a constituent of the urinary secretions of surgical maggots and of common occurrence in plants and animals, has been found to stimulate healing, with abundant growth of healthy granulation tissue in slowly healing suppurative wounds. The excretion of this substance into the wound is doubtless one of the factors contributing to the remarkable healing effects obtained in maggot therapy, but the claim is not made that it can be substituted for maggots. Allantoin can be obtained commercially. It is bland, stable, and harmless; it has no odor and is nonstaining. The treatment is simple, painless, and inexpensive.

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FRACTURES OF THE FOREARM

An Analysis of 415 Cases with Special Reference to Disabilities

BY BARNEY J. HEIN, M.D., F.A.C.S., TOLEDO, OHIO

This treatise is a study of the end results in 415 fractures of the forearm, considering both anatomical and functional results, as well as the actual time lost. The cases occurred consecutively in the private and industrial practice of the author in the last eight years.

For the purpose of the study the fractures are grouped, according to location, in the lower, middle, and upper thirds of the forearm. Because of their special problems, fractures in the Colles' area, the head of the radius, and the olecranon are considered separately. The distribution is as follows:—

Colles' area	159
Radius, lower third	33
Ulna, lower third	7
Radius and ulna, lower third	39
Radius, middle third	6
Ulna, middle third	11
Radius and ulna, middle third	22
Radius, upper third	1
Radius, head	40
Ulna, upper third	12
Olecranon	16
Radius and ulna, upper third	4
Patients	350

In sixty-five of these 350 patients both the ulna and radius were fractured, making the total of 415 individual fractures. In thirty-three of the fractures of the radius in the Colles' area, the tip of the styloid process of the ulna also was fractured, but this is not regarded separately. It is interesting to note that 277 fractures (66.7 per cent.) occurred in the lower third of the forearm; 61 fractures (14.7 per cent.) in the middle third, and 77 (18.5 per cent.) in the upper third.

Figure 1 illustrates graphically the anatomical distribution.

In analyzing the cases according to age, it was found that fractures may occur in any region at any age, but the majority in this series occurred during the period of greatest physical activity (See Table I).

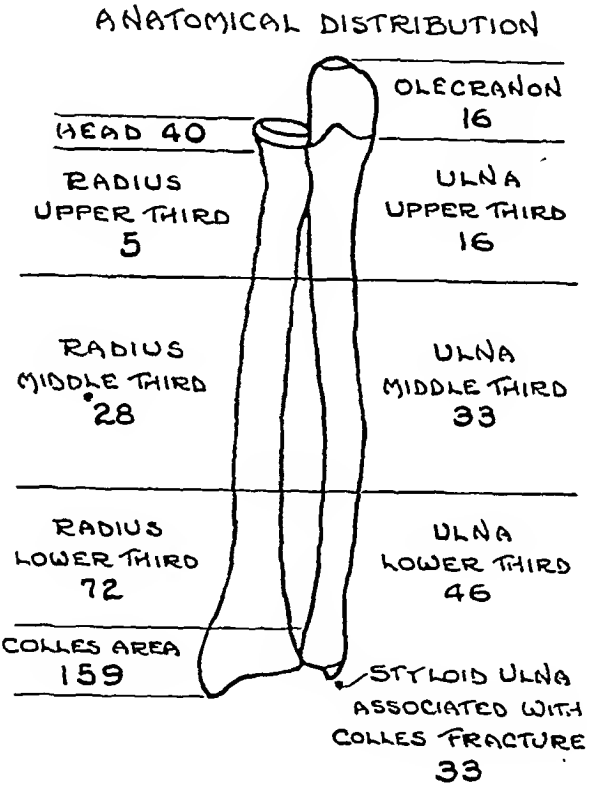
Twenty-five per cent. of all fractures and thirty-five per cent. of the fractures situated in the lower third of the forearm occurred before the age of twenty.

Types: In most instances it is obvious to which class various fractures belong; nevertheless, in some the classification is difficult and here the author has used his judgment. Table II represents the types of the fractures. There was a predominance of simple transverse (47.4 per

cent.), followed by simple comminuted (17 per cent.), then by simple oblique (8.6 per cent.), etc.

Methods: No attempt has been made to describe in detail the various forms of treatment used. Where reference to treatment has been made, it was considered important from the standpoint of end results and disability. When displacement occurred, reduction was usually made with the aid of the fluoroscope. Retention was accomplished by conventional means,—either plaster or coaptation splints; and baking, massage and motion were started as early as was consistent with good results.

FIG. 1



For the estimation of end results, both anatomical and functional, the classification of good, moderate, and bad, as adopted by the American Surgical Association for Industrial Hospitals, has been used throughout the study.

Disabilities: In each group where there were enough cases, disabilities have been considered as to age, ability to do heavy duty, joint involvement, etc. In estimating time lost only uncomplicated cases have been considered, except when specifically stated. Of importance is the fact that 19.4 per cent. of all the fractures had serious complicating injuries which lengthened disability.

FRACTURES IN COLLES' AREA (FIGS. 2-A AND 2-B)

This group includes all fractures of the lower one inch of the radius. It comprises 159 cases, in 100 of which the fragments were displaced and in 59 of which they were not. The right wrist was broken in 88 cases; the left in 71; in 4 cases both wrists were fractured. In 71 instances the fracture line involved the wrist joint, while in 88 there was no joint involvement. Of the 100 patients with fractures in which the fragments

were displaced, 82 received general anaesthesia, and 3 local anaesthesia. In 12 cases no anaesthesia was needed; these were seen very early, before swelling had occurred, and reduction was not difficult. Two patients required a second anaesthetic.

In the thirty-three patients who had fracture of the ulnar styloid process, associated with a fracture of the lower end of the radius, the former was disregarded and in no instance did it cause any added disability. It is the writer's opinion that these fractures of the styloid process are often overlooked.

The position most commonly used in splinting was with the wrist

TABLE I

AGE INCIDENCE

Location of Fracture	1-9 Years	10-19 Years	20-29 Years	30-39 Years	40-49 Years	50-59 Years	60-69 Years	70-79 Years	80-89 Years	Total
Colles'....		26	19	33	32	29	16	4		159
Radius, lower third...	9	15	4	2	1	2				33
Ulna, lower third...		3	2	1			1			7
Radius and ulna, lower third...	8	23	1	3	2		2			39
Radius, middle third...	1		2		2	1				6
Ulna, middle third	1		6	1	1	1		1		11
Radius and ulna, middle third...	8	3	1	5	3		1		1	22
Radius, upper third...	1									1
Ulna, upper third		1	2	7		1	1			12
Radius and ulna, upper third	1	1		2						4
Olecranon.	1	3	4	4	1	2	1			16
Head of radius..	1	2	10	18	5	2	2			40
Total.....	31	77	51	76	47	38	24	5	1	350

TABLE II

TYPES OF FRACTURES

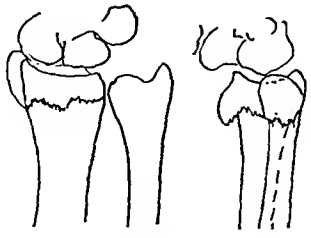
Location of Fracture	Simple Transverse	Simple Oblique	Simple Comminuted	Compound Oblique	Compound Comminuted	Greenstick	Longitudinal	Epiphyseal	Incomplete	Tearing Fracture of Cortex	Subperiosteal	Styloid of Radius	Head Comminuted	Chip off Head	Fracture through Neck	Ulnar Styloid Uncomplicated	Coronoid Process	Reverse Colles'
Colles'	74	5	60		2		2	4	5	2	1	2						2
Radius, lower third	22	1			1	7			2									
Ulna, lower third	3				1	1										2		
Radius, lower third;	27	4	3	1	1	3												
and ulna, lower third	28	3	1	1	3	3												
Radius, middle third	1	3	1		1													
Ulna, middle third	3	6	1		1													
Radius, middle third;	12	5		1	2	2												
and ulna, middle third	10	5	2	1	2	2												
Radius, upper third	1																	
Ulna, upper third	4	2															6	
Radius, upper third;	1		1		1	1												
and ulna, upper third					3	1												
Olecranon	11	1	2		1			1										
Head of radius							4						26	8	2			
Total	197	35	71	4	19	20	6	5	7	2	1	2	26	8	2	2	6	2

FIG. 2-A

COLLES' FRACTURES (DISPLACED).

Tracings from roentgenograms. Results with periods of disability.

Before

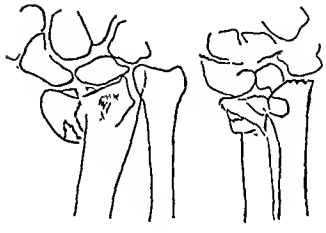


After

Case 1

Case 1

Mrs. S., aged 57 years.
Type: simple comminuted.
Result: good anatomical, good functional.
Occupation: housework.
Disability: 5 weeks.



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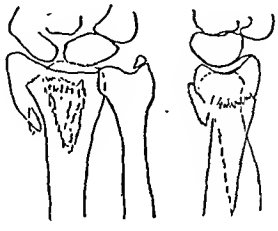
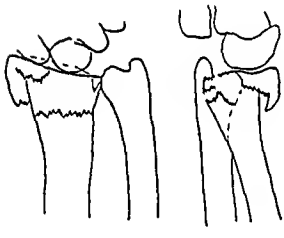


After

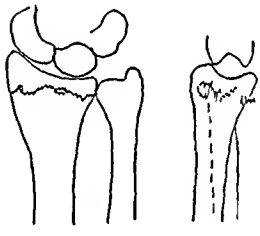
Case 2

Case 2

Mrs. I. G., aged 76 years.
Type: simple comminuted.
Result: poor anatomical, moderate functional. (Prominent ulnar styloid, with considerable radial deviation of hand.)
Occupation: housework, retired.
Disability: 8 weeks.



Before

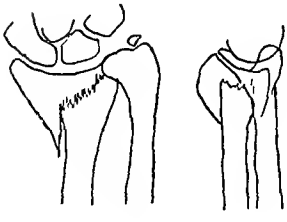


After

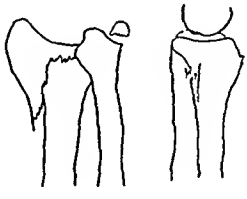
Case 3

Case 3

Mrs. L. B., aged 30 years.
Type: simple transverse.
Result: good anatomical, good functional.
Occupation: housework.
Disability: 5 weeks.



Before



After

Case 4

Case 4

Mrs. J. R., aged 81 years.
Type: simple comminuted.
Result: moderate anatomical and good functional.
Occupation: retired.
Disability: 6 weeks.

straight; this position was used in 108 cases. In forty-nine the wrist was placed in various degrees of flexion and retained by means of a posterior plaster splint. This is a position that holds the fragments well, but the wrist should be straightened at about the tenth day if shortening of the flexors is to be avoided. This complication is prone to happen in older people and for that reason the flexed position is being abandoned in the treatment of the aged. In two cases of reverse Colles' fracture, the wrists were placed in hyperextension. In no instance among the four cases of fresh fracture engrafted upon an old Colles' fracture, which had

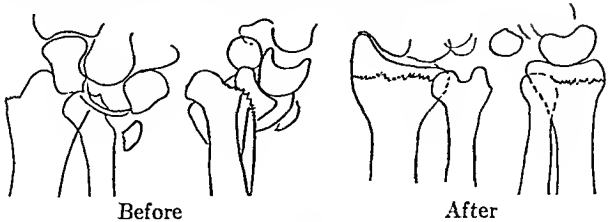
FIG. 2-B

COLLES' FRACTURES (DISPLACED).

Tracings from roentgenograms. Results with periods of disability.

Case 5

L. H., aged 44 years.
Type: simple transverse.
Result: good anatomical, good functional.
Occupation: machine operator.
Disability: 5¼ weeks.

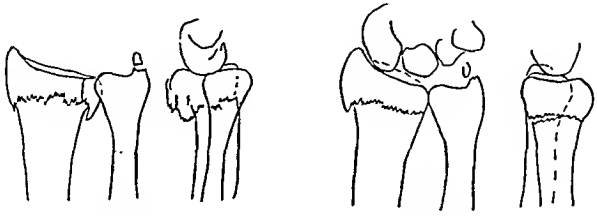


Before After

Case 5

Case 6

Mrs. C. R., aged 51 years.
Type: simple comminuted.
Result: moderate anatomical, moderate functional.
Occupation: housework.
Disability: 6 weeks.
Two attempts at reduction were made.

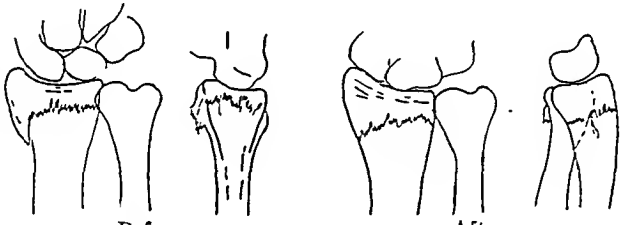


Before After

Case 6

Case 7

A. M., aged 32 years.
Type: simple comminuted.
Result: good anatomical, good functional.
Occupation: salesman.
Disability: 6 weeks.

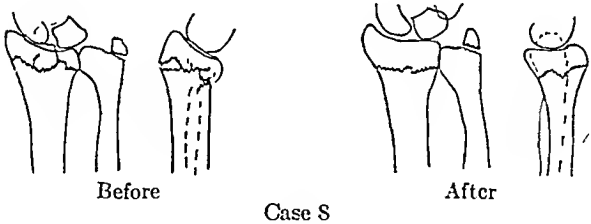


Before After

Case 7

Case 8

Mrs. B. L., aged 64 years.
Type: simple transverse.
Result: good anatomical, good functional.
Occupation: housework.
Disability: 6 weeks.



Before After

Case 8

healed with deformity, were we able to improve the old deformity, although good union was obtained in each case.

Results:

All Colles' fractures, regardless of complications, showed the following results:

(*a*)	Anatomical	Good	127	79.8 per cent.
		Moderate	27	16.9 per cent.
		Bad	5	3.3 per cent.
(*b*)	Functional	Good	136	85.5 per cent.
		Moderate	21	13.2 per cent.
		Bad	2	1.3 per cent.

Analyzing the moderate anatomical results, one finds many interesting complications elsewhere, which influenced the outcome considerably. These were specifically:

1. Fracture of the femur, with bad general condition.
2. Dislocation of the elbow.
3. Arteriosclerosis; only fair position of the fragments.
4. Fracture of the skull and other serious injuries.
5. Myocarditis,—anaesthesia contra-indicated.
6. Extreme swelling after reduction, requiring release of splints.
7. New fracture in an old deformity (three cases).
8. Fracture of the skull.
9. Dislocation of semilunar bone of wrist and multiple fractures of the pelvis, ribs, jaws, etc.
10. Compound fracture of the femur with compound dislocation of the elbow.
11. Fracture of the humerus and myocarditis.
12. Old age,—general condition such as not to warrant any procedure.
13. Passive congestion of the wrist and forearm from previous amputation of breast, and old fracture of wrist with some deformity.
14. Fracture of the clavicle.
15. Fractures of cuneiform bone, tibia, and fibula, and transverse processes of the vertebrae.
16. Two weeks' delay in reduction.

In nine cases of moderate anatomical results, there were no complications. In the five cases in which bad anatomical results were obtained one finds:

1. Displacement after reduction, resulting in delayed union.
2. Fresh Colles' fracture engrafted upon an old fracture which had healed with deformity.
3. Comminution of fragments, incapable of retention.
4. Comminution of fragments, with fracture also of head of the radius. Head of radius was removed and there was considerable shortening of the radius.
5. Colles' fracture, complicated with fracture of head of the radius and chronic chorea.

In dividing the thirty-two cases of moderate and bad anatomical results into types of fractures, one finds that there were twenty-four comminuted fractures, resulting in twenty moderate and four poor anatomical results. There were six transverse fractures, yielding five moderate and one poor anatomical result. Two oblique fractures accounted for two moderate anatomical results.

The anatomical and functional results did not always correspond,—for instance, in five bad anatomical results, only two were bad functionally, and three were classified as moderate functional results.

Of twenty-seven moderate anatomical results, eighteen yielded moderate, and nine good functional results. Four good anatomical results gave only moderate functional results. Of these, two were complicated with rheumatism, one with a posterior dislocation of the elbow, and one had no complications.

The causes of moderate or poor anatomical results were, primarily, imperfect reduction, or inability to maintain reduction, manifested later by:

1. Various degrees of change (tilting) of the radial articular surface in its relation to the shaft of the radius.
2. Shortening of the radius in varying degrees, especially in comminuted fractures, resulting in radial deviation of the hand.
3. Widening of the wrist.
4. Prominence of lower end of ulna.

The moderate and bad functional results revealed:

1. Varying degrees of limitation in the wrist joint, most marked in flexion.
2. Varying degrees of impairment in finger function, generally due to arthritic tendencies. There were four cases of arthritis in this series.
3. Weakness.
4. Pain.

Disabilities:

The average period of disability of all cases in this group of Colles' fractures, regardless of complications, was 8 weeks. Twenty-nine of them had serious complications. The uncomplicated cases, 130 in number, had an average disability of 6.2 weeks, but if heavy manual labor had to be done, even though the fractures were uncomplicated (40 cases), 8.7 weeks elapsed before the patients were able to work. In the group of fractures which were displaced and required reduction, but were not complicated by other serious injury, the average time lost was 7.4 weeks, while in the group with no displacement (38 cases) the average time lost was 5.8 weeks.

The average disability of sixty-one simple transverse fractures, not involving the wrist joint, was 6.2 weeks, while in fifty-five comminuted fractures involving the wrist joint the average disability was 8+ weeks.

Disability grouping according to age was:

10 to 19 years (21 cases)	4.9 weeks
20 to 29 years (15 cases)	5.6 weeks
30 to 39 years (27 cases)	6.7 weeks
40 to 49 years (27 cases)	7.2 weeks
50 to 59 years (18 cases)	7.9 weeks
60 to 69 years (12 cases)	7.0 weeks
70 to 79 years (4 cases)	6.75 weeks

In those patients below twenty years of age (the school group), 4.9 weeks represented the time the part was immobilized and protected, rather than a disability to work. It will also be noted that the groups from sixty to eighty years show a slight shortening of disability over those preceding. This is accounted for by the fact that these older patients have passed the period of physical activity and splinting was, therefore, dispensed with sooner.

In the four cases with both radii involved, the average disability was 11+ weeks.

Union: In this group bony union occurred in every case. No open reductions were considered necessary. In only one was union delayed (fifteen weeks), and this was from slipping of the fragments after reduction. In all other cases with disability of over eight weeks, the cause was other concurrent injuries more disabling than the wrist fractures.

FRACTURES OF THE LOWER THIRD OF THE RADIUS

This group comprised 7.9 per cent. of the total number of forearm fractures. There were thirty-three cases, and 72.7 per cent. of this number occurred before the age of twenty (See Table I). Since this fracture is an injury of the young, happening mostly in play, it is interesting to note that all patients in this group were quite free from serious complicating injuries. The right side was involved nineteen times, the left fourteen. There was a predominance of males,—twenty-four to nine. Twenty-three fractures were displaced and required reductions; of these sixteen were angulated and seven were overriding. Fourteen of these patients were given general anaesthesia, and one local; while eight of the fractures with angulation were seen early and reduced without anaesthesia.

The predominant type of fracture in this group was the simple transverse, occurring in twenty-two cases; followed by the greenstick in seven cases; incomplete, two; simple oblique, one; and compound comminuted, one.

Usually treatment is not difficult, and reduction is generally a simple matter. After reduction has been accomplished, there is very little tendency to displacement and retention either in plaster or coaptation splints is satisfactory.

If difficulty in holding the position is encountered, it is usually in the simple oblique and comminuted, displaced types. The intact ulna acts as an efficient aid to splinting in all fractures of the shaft of the radius; it maintains position and prevents overriding.

Fixation: Seven of this group of fractures of the lower radius had casts applied and twenty-six had coaptation splints. Following the correction of angulation, it was often deemed advisable to use felt pressure pads, which could easily be adjusted if necessary, in conjunction with the coaptation splints. In all fractures of the forearm, with the exception of Colles' fracture, it has been the custom to immobilize the hand and wrist as well as the elbow. In Colles' fracture the elbow was not splinted.

Disabilities:

In the patients below twenty years of age (twenty-four cases), the average disability was 4.3 weeks. In those above twenty years, six cases required 5.5 weeks, while four whose work was heavy had disabilities of 5.1 weeks.

Two cases with prolonged disabilities were not considered. One of these had an overriding of four months' duration before treatment. An open reduction was performed and good anatomical and functional results were obtained, though with a disability of nine months. The other was a case of non-union in a luetic, who had been previously operated upon unsuccessfully. The ends of the fragments were freshened and good reposition obtained, but again there was failure. The wound became infected and non-union, with a bad anatomical result, followed. The disability in this case was fifty-two weeks.

Results:

(*a*)	Anatomical	Good	30
		Moderate	1
		Bad	1
(*b*)	Functional	Good	31
		Moderate	0
		Bad	1

NOTE: One patient was not included in the above, as death supervened from a fracture of the skull.

The one case classified as a moderate anatomical result was complicated by a compound dislocation of the lower end of the ulna, with a tearing of the ligaments between the radius and ulna. The result, however, was good functionally, though the wrist was widened and the ulnar styloid was prominent. The bad anatomical result was in the luetic above mentioned.

Union was usually rapid and obtained in all cases in this group except in the luetic, in which case infection followed operation.

FRACTURES OF MIDDLE THIRD OF RADIUS

Fractures in this region of the radius were much more uncommon than in the lower third. Only six occurred, constituting only 1.4 per cent. of the total number; no age group seemed to be particularly susceptible (Table I), and the simple oblique type of fracture predominated (Table II). All occurred in males, each side being involved three times. In three cases the fragments were displaced and required reduction. There was one compound comminuted fracture, the result of a gunshot wound. In this a débridement was performed, the wound healed promptly, and the fragments united in good position with good function.

One oblique fracture, complicated by a fracture of the skull, was operated on three times before union was secured. The first operation was delayed three weeks on account of the complication; the result was

non-union. At the second operation the ends were freshened and wrapped with osteoperiosteal-wafer grafts from the tibia; non-union again occurred. At the third operation a large onlay graft was used and union was finally obtained. The length of time required was two years.

Results:

(*a*)	Anatomical	Good	4
		Moderate	2
		Bad	0
(*b*)	Functional	Good	4
		Moderate	2
		Bad	0

Disabilities: In comparison with fractures of the lower third of the radius, the periods of disability in this group averaged about twice as long. In four cases, over twenty years of age (working class), the average time lost was 10.5 weeks; while two patients doing heavy labor, before they returned to their occupation, lost 13 weeks. In one case, age two, the time was 4

TABLE III

FRACTURES OF THE HEAD OF THE RADIUS (NOT DISPLACED)
RESULTS

Case	Pain	Limitation in Extension	Limitation in Flexion	Limitation in Pronation and Supination	Complications
1	No	No	No	No	
2	No	No	No	No	
3	No	No	No	No	
4	No	No	No	No	
5	No	40 degrees	20 degrees	No	Fractured olecranon which was sutured. Crepitus over head.
6	No	No	No	No	
7	No	No	No	No	
8	No	No	No	No	
9	No	No	No	No	
10	No	No	No	No	
11	No	No	No	No	
12	No	No	No	No	
13	No	15 degrees	No	No	Lateral dislocation of elbow.
14	No	No	No	No	
15	No	No	No	No	
16	No	No	No	No	
17	No	No	No	No	Compound fracture of both patellae.
18	No	No	No	No	Fracture of lower end of humerus.

weeks. The one with an oblique fracture, requiring three operative procedures already described, had a disability of two years. Two of the six cases were complicated by fractures of the skull. Union occurred in all cases of this group. Accurate reductions are essential in this region for good results and minimum disabilities.

FRACTURES OF UPPER THIRD OF RADIUS

Since there was only one case in this group, no deductions could be made. The patient was a boy of nine years with a simple transverse fracture; the fragments were displaced. It was complicated with a supracondylar fracture, and posterior displacement of elbow. The supracondylar fracture was reduced, and fair position secured in the radius, with immobilization in acute flexion. The result was a moderate anatomical and a moderate functional one, with considerable limitation in pronation and supination. The time under observation and splinting was ten weeks.

FRACTURES OF HEAD OF RADIUS (FIGS. 7-A AND 7-B)

Of the forty cases in this group, the greatest number occurred during the period of greatest activity (Table I), and only three occurred below the age of twenty. The males were twenty-five in number; the females, fifteen. The right arm was involved twenty-five times; the left, fifteen times. The most common type of fracture of the head was the comminuted, which occurred in twenty-six instances, followed by the chip off the head in eight cases, longitudinal fracture in four, and transverse fracture through the neck in two cases. Displacement occurred in twenty-

TABLE IV

HEAD OF THE RADIUS (DISPLACED), NO RESECTION
RESULTS

Case	Displacement	Pain	Limitation in Extension	Limitation in Flexion	Limitation in Pronation and Supination	Crepitus over Head	Complications
1	Slight	Yes	15 degrees			Yes	
2	Yes	No	20 degrees	15 degrees	Slight		Fracture of lower end of humerus.
3	Slight	No	60 degrees	45 degrees	Some	Yes	Posterior dislocation of elbow.
4	Slight	No	10 degrees				
5	Yes	No	No report				Posterior dislocation of elbow.
6	Yes	Yes	30 degrees	15 degrees	Some		Fracture of lower end of radius. Chronic chorea.
7	Slight	No	20 degrees			Yes	

two cases and in fifteen of these resections were done. In eighteen the fragments were not displaced and these cases were treated conservatively. In twelve of the cases with displacement there were associated dislocations of the elbow, classified as follows: posterior, ten; anterior, one; lateral, one.

Other associated complications were: fracture of the olecranon in two cases; fracture of the coronoid process in one case; fracture of the lower end of the humerus in four cases; fracture of the lower end of the radius in two cases; fractures of the radius and ulna in one; and intercarpal dislocations in two. The dislocations of the elbow were of sufficient frequency to be considered a likely complication of all fractures of the head of the radius. A fracturing force exerted along the shaft of the radius, causing the radial head to break against the capitellum, if carried through, will result either in a posterior dislocation of the elbow or an anterior dislocation of the radius, depending upon the degree of flexion present in the elbow joint when this force is received. This same force may also account for the fractures of the coronoid process and of the olecranon, which are occa-

TABLE V

HEAD OF THE RADIUS (DISPLACED), RESECTED EARLY RESULTS

Case	Displacement	Pain	Limitation in Extension	Limitation in Flexion	Limitation in Pronation and Supination	Complications
1	Yes	No	10 degrees			
2	Yes	No	15 degrees			Fracture of tip of coronoid. Posterior dislocation of elbow.
3	Yes	No	20 degrees			Fracture of olecranon. Sutured.
4	Yes	No	10 degrees			Fracture of patella. Posterior dislocation of elbow.
5	Yes	No	20 degrees			Posterior dislocation of elbow.
6	Yes	No	25 degrees	30 degrees	20 degrees	Intercarpal dislocation. Posterior dislocation of elbow. Diabetes.
7	Yes	No	10 degrees			
8	Yes	No	45 degrees	20 degrees	50 degrees	Posterior dislocation. Fracture of lower end of humerus.
9	Yes	No	15 degrees			Posterior dislocation of elbow.
10	Yes	No	15 degrees			

sional complications. This mechanism of the fracture is important for it signifies that there is often a severe injury to other ligaments about the elbow as well as to the orbicular. Probably in many cases there is damage to these ligaments, but in the absence of a frank dislocation, the degree of damage cannot be so easily determined.

Results:

In studying the results, the cases were divided into four groups: (See Tables III, IV, V, and VI.)*

(*a*) Not displaced and treated conservatively (eighteen cases).
(*b*) Displaced and treated conservatively (seven cases).
(*c*) Displaced and resected early (ten cases).
(*d*) Displaced and resected late (five cases).

(*a*) In the non-displaced group of eighteen cases, sixteen had normal results. One presented a limitation in extension of the elbow of 40 degrees and a limitation in flexion of 20 degrees. In this case the olecranon was fractured and required suturing. A second case had a limitation in extension of 15 degrees; otherwise the result was normal. This case was complicated with a lateral dislocation (Fig. 7-A, Case 32). In no case in this group was there a complaint of pain.

(*b*) Displaced but treated conservatively (seven cases): In four cases the displacement was considered very slight. All of the remaining

TABLE VI

HEAD OF THE RADIUS (DISPLACED), RESECTED LATE RESULTS

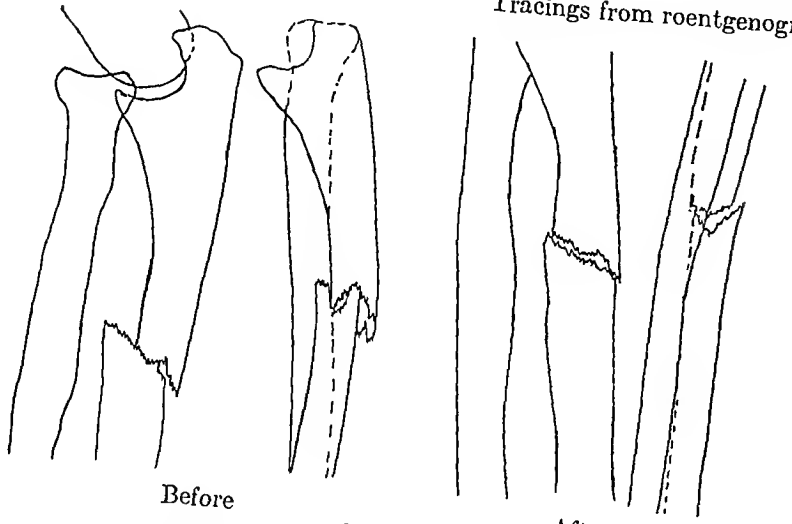
Case	Displacement	Pain	Limitation in Extension	Limitation in Flexion	Limitation in Pronation and Supination	Complications
1	Marked	No	Marked	Marked	Marked	Musculospiral paralysis. Old posterior dislocation of elbow.
2	Marked	Yes	30 degrees	20 degrees	30 degrees	Fracture of lower end of radius.
3	Marked	Yes	20 degrees	25 degrees	25 degrees	Exaggeration of radial shaft with anterior dislocation.
4	Marked	Yes	30 degrees	10 degrees		Paralysis of median nerve. Fracture of lower end of humerus. Loss of soft parts of elbow. Posterior dislocation.
5	Marked	No	60 degrees	40 degrees	Complete loss	

*The case numbers in these tables do not correspond to the case numbers shown on the illustrations.

FIG. 3

FRACTURES OF THE ULNA.

Tracings from roentgenograms. Results with periods of disability.

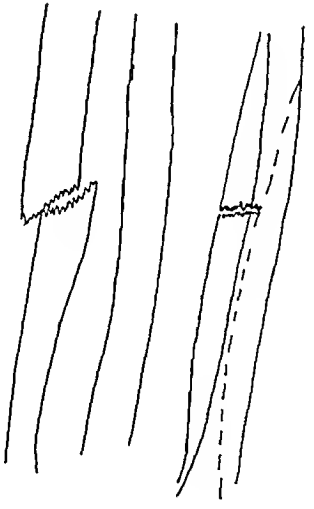


Before

After

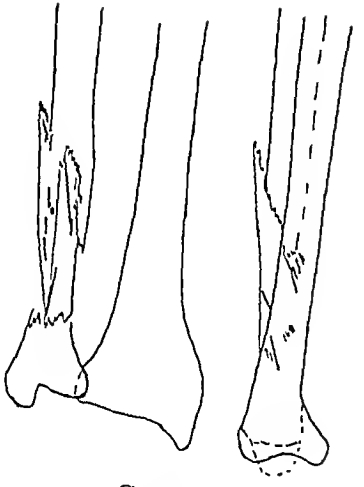
Case 9

Mrs. B. K., aged 35 years.
Type: simple oblique, with anterior dislocation of head of radius.
Result: good anatomical, good functional.
Occupation: housework.
Disability: 5 weeks.



Case 10

H. W., aged 24 years.
Type: simple oblique.
Result: good anatomical, good functional.
Occupation: salesman.
Disability: 5 2/7 weeks.



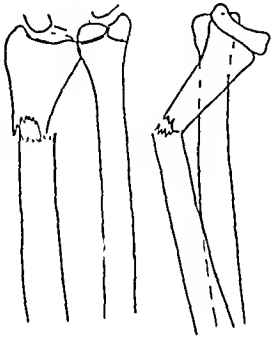
Case 11

W. Y., aged 68 years.
Type: compound, comminuted.
Result: good anatomical, good functional.
Occupation: railroad man.
Disability: 20 weeks.
Extensive laceration of hand, same side.

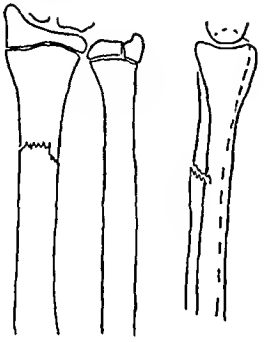
FIG. 4

FRACTURES OF THE RADIUS.

Tracings from roentgenograms. Results with periods of disability.



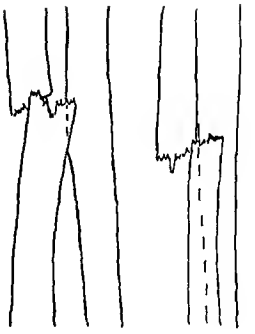
Before



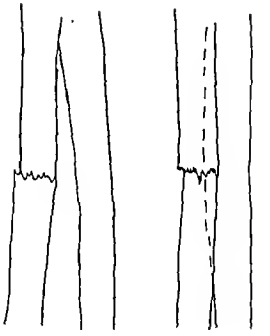
After

Case 12

R. S., aged 13 years.
Type: simple transverse, angulation.
Result: good anatomical, good functional.
Occupation: school.
Disability: 6 weeks.



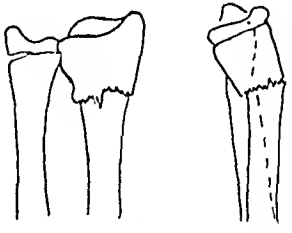
Before



After

Case 13

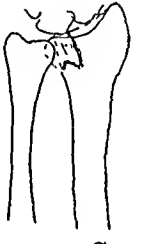
E. L., aged 55 years.
Type: simple transverse.
Result: good anatomical, moderate functional.
Occupation: blacksmith.
Disability: 16 weeks.
Complication: fracture of skull.
Slight stiffness in finger function.



Case 14

Case 14

P. G., aged 14 years.
Type: buckling, with angulation.
Occupation: school.
Result: good anatomical, good functional.
Seen early and reduced without anaesthesia.
Disability: 5 weeks.



Case 15

Case 15

Mrs. I. B., aged 56 years.
Type: simple comminuted fracture into radio-ulnar articulation.
Complications: subglenoid dislocation of shoulder same side, rheumatism.
Occupation: housework.
Results: good anatomical, good functional.
Disability: 10 weeks.

three had complications (See Table IV). These were manipulated under anaesthesia. All of these patients had some limitation in extension, three some limitation in flexion, and three some limitation in pronation and supination. Three had crepitus over the head of the radius on rotation for months afterward. Two complained of pain afterward.

(*c*) Displaced and resected early (ten cases): In these cases there were uniformly good, although not perfect results. None of the patients complained of pain. All had limitation in extension of from 10 to 15 degrees. Two had limitation in flexion. Two had limitation in pronation and supination, which in one case was quite marked (Table V).

(*d*) Displaced and resected late (five cases): In all of these cases there was marked displacement and in four there were serious complications (Table VI). All showed marked limitation in extension and flexion of the elbow; and in four cases there was marked limitation in pronation and supination. One patient had complete loss of rotation.

Time Lost:

(*a*) Not displaced: average disability, 4.66 weeks.
(*b*) Displaced, not resected: average disability, 10 weeks.
(*c*) Displaced and resected early: average disability, 8.5 weeks.
(*d*) Displaced and resected late: average disability, 23 weeks.

NOTE.—All resections were complete. No resections were made in the young; in this group we recommend operative replacement of the head if possible. The writer's experience with the manipulative treatment in fractures with displacement has not been satisfactory.

In the entire series there were seventeen cases with serious complications which no doubt affected the disabilities and results; fifteen of these occurred in the displaced groups. Complications should be given due consideration in prognosis.

Non-displaced fractures of the head of the radius treated conservatively gave uniformly good results. Displaced fractures treated conservatively did not give as good results as those resected. Early resection yielded better results than late.

FRACTURE OF THE LOWER THIRD OF ULNA

There were seven cases in this group, or 1.6 per cent. of the entire series, the fractures occurring in six males and one female. In two cases the ulnar styloid alone was fractured. Two fractures were displaced and required reduction under anaesthesia. The simple transverse type predominated, being present in three cases. There was one greenstick and one compound comminuted fracture. The latter (Fig. 3, Case 11) was accompanied by extensive injuries to the soft parts of the forearm and hand. In this case a débridement was performed before reduction was made.

Reduction in fractures in this region is ordinarily not difficult and immobilization is accomplished by a plaster cast with the wrist in the posi-

tion of rest. In all fractures of the forearm during immobilization, the early use of the fingers was encouraged.

Good anatomical and good functional results were obtained in all cases. The average period of disability was nine and two-sevenths weeks. This includes one case of delayed union requiring thirteen weeks and a second case requiring sixteen weeks because of an injury to the hand. The average disability in four uncomplicated cases was six and two-sevenths weeks. The average disability in the two cases of fracture of the ulnar styloid, both occurring in men doing hard labor, was six and one-seventh weeks.

Firm bone union was obtained in all cases.

FRACTURE OF THE MIDDLE THIRD OF THE ULNA

This group consisted of eleven cases, or 2.6 per cent. of the total series. There were ten males and one female. Two of the fractures were displaced and required manipulation. With the exception of one case, all occurred above the age of twenty (Table I). The simple oblique type of fracture was present in six cases; simple transverse, in three cases; simple comminuted and compound comminuted, in one case each. There was an anterior dislocation of the head of the radius accompanying the fracture in one case. The anterior dislocation of the head of the radius occurred twice in this series with fractures of the ulna (Fig. 3, Case 9). Whenever the ulna is fractured alone and there is overriding of the fragments, this dislocation should be looked for. It can easily be diagnosed clinically by the marked limitation in flexion of the elbow.

Reduction is usually not difficult, and here also accuracy in reduction is essential for early healing and minimum disability. Immobilization is obtained in a plaster cast.

Results: All cases in this group were classified as good anatomical and good functional results.

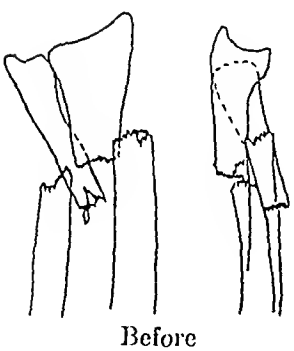
Disabilities: As in fractures of the middle third of the radius, fractures in the middle of the ulna required longer healing periods than those in the lower third of the same bone, and the time of disability was longer. In seven uncomplicated cases the average disability was eight and one-seventh weeks. In two cases, both non-displaced, there was delayed union requiring eleven and one-seventh weeks and sixteen weeks respectively.

FRACTURE OF THE UPPER THIRD OF THE ULNA

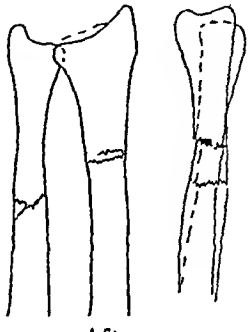
There were twelve fractures in this group, or 2.8 per cent. of the total number; nine occurred in males and three in females. Four cases were of the simple transverse type; two were simple oblique; while the coronoid process was fractured six times. Seven fractures in this group occurred between the ages of thirty and thirty-nine years, only one being present before the age of twenty. In only one case was there displacement, requiring reduction. In this case there was also the complication of an an-

FIG. 5-A

FRACTURES OF RADIUS AND ULNA, LOWER THIRD (DISPLACED).
Tracings from roentgenograms. Results with periods of disability.



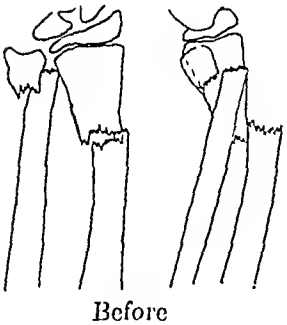
Before



After

Case 16

Case 16
P. W., aged 18 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 10 weeks.



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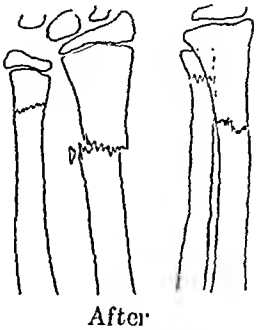
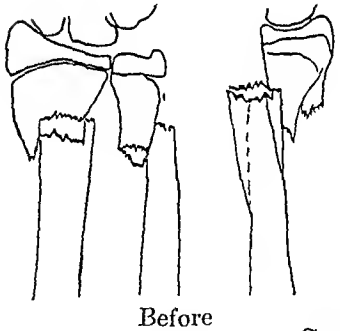


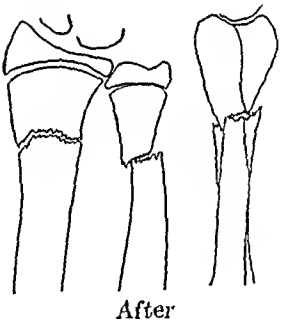
After

Case 17

Case 17
R. S., aged 12 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 6¾ weeks.



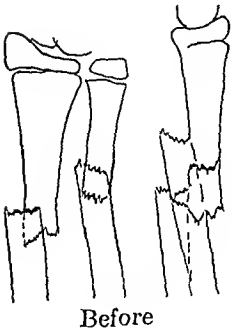
Before



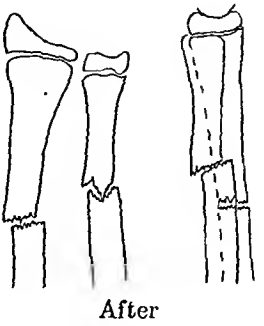
After

Case 18

Case 18
H. W., aged 18 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 7 weeks.



Before



After

Case 19

Case 19
J. B., aged 11 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 5 weeks.

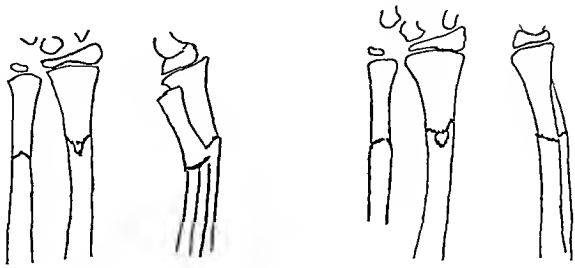
FIG. 5-B

FRACTURES OF THE RADIUS AND ULNA, LOWER THIRD (DISPLACED).

Tracings from roentgenograms. Results with periods of disability.

Case 20

S. N., aged 11 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 5 weeks.

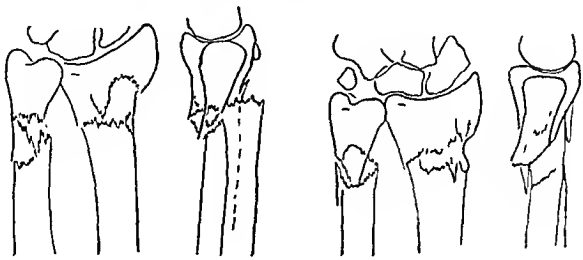


Before After

Case 20

Case 21

H. K., aged 67 years.
Type { Radius: simple, comminuted. Ulna: simple comminuted.
Complications: fracture of head of humerus, same side.
Result: poor anatomical, poor functional.
Occupation: laborer.
Disability: permanent partial disability.
Failed to return for treatment.

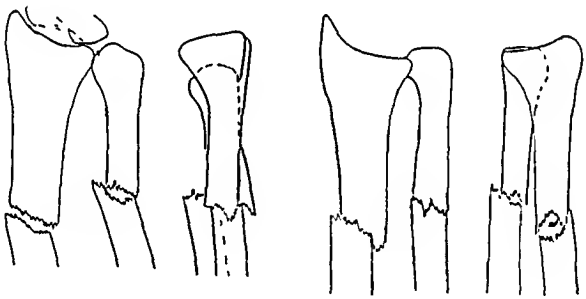


Before After

Case 21

Case 22

J. S., aged 18 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 14 weeks.

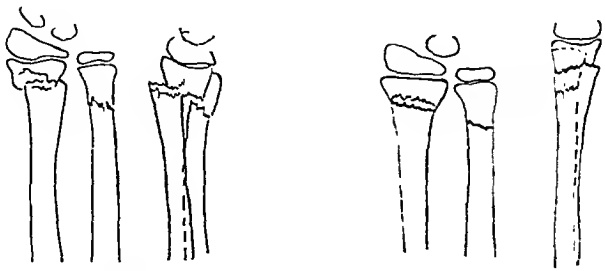


Before After

Case 22

Case 23

J. Z., aged 10 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 5 weeks.

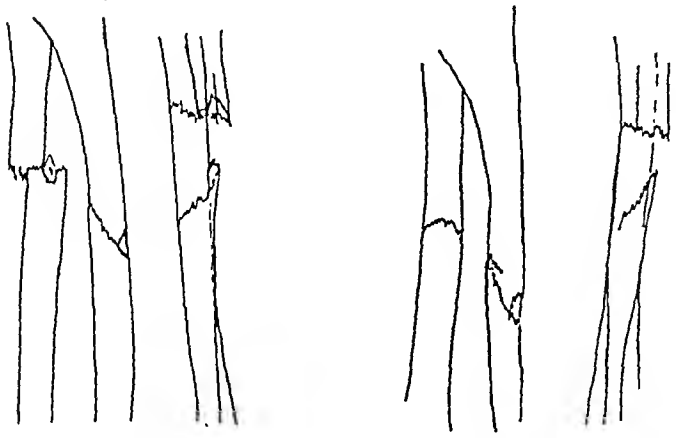


Before After

Case 23

FIG. 6-A

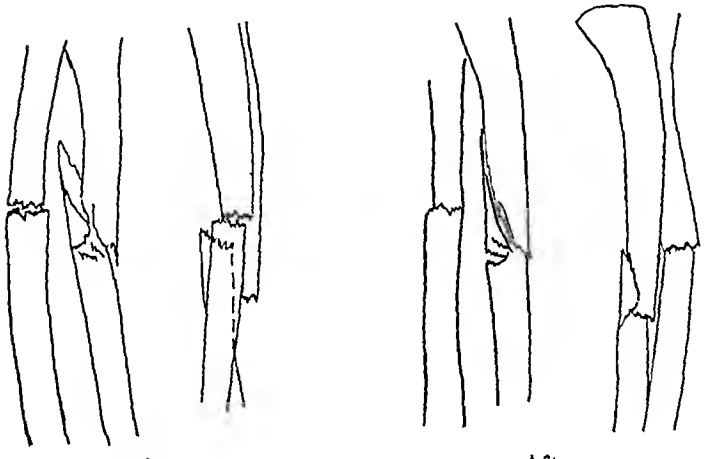
FRACTURES OF THE RADIUS AND ULNA, MIDDLE THIRD (DISPLACED).
Tracings from roentgenograms. Results with periods of disability.



Before After

Case 24

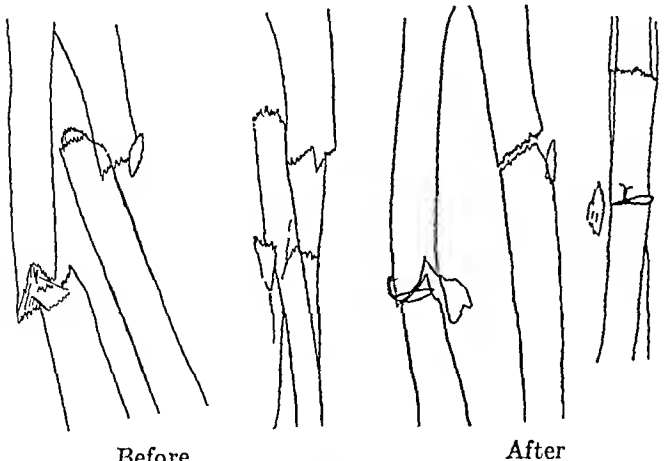
Case 24
F. V., aged 18 years.
Type { Radius: transverse. Ulna: compound, comminuted.
Result: good anatomical, good functional.
Occupation: school.
Disability: 8 weeks.



Before After

Case 25

Case 25
L. H., aged 36 years.
Type { Radius: simple transverse, displaced. Ulna: simple, comminuted, displaced.
Result: good anatomical, good functional.
Occupation: nurse.
Disability: 20 weeks.



Before After

Case 26

Case 26
E. E., aged 32 years.
Type { Radius: simple oblique. Ulna: simple, comminuted.
Open reduction of both bones, with silver wire to radius.
Complications: fractured skull, and fractured jaw.
Result: good anatomical, good functional.
Occupation: machinist.
Disability: 12 weeks.

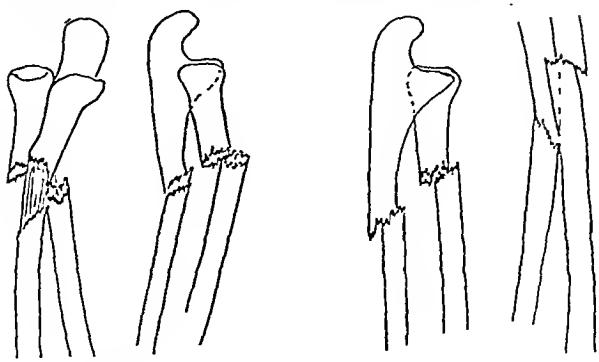
FIG. 6-B

FRACTURES OF THE RADIUS AND ULNA, MIDDLE THIRD (DISPLACED).

Tracings from roentgenograms. Results with periods of disability.

Case 27

V. H., aged 15 years.
Type { Radius: simple oblique. Ulna: simple oblique.
Complications: fracture of left femur, fragilitis ossium.
Result: moderate anatomical, good functional.
Occupation: school.
Disability: 19 weeks.

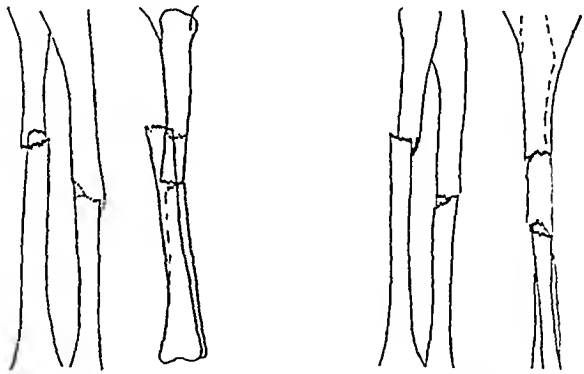


Before After

Case 27

Case 28

G. M., aged 7 years.
Type { Radius: simple transverse. Ulna: simple transverse.
Result: good anatomical, good functional.
Occupation: school.
Disability: 8 weeks.

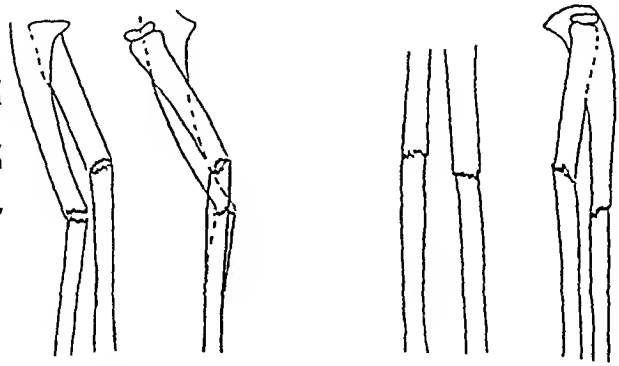


Before After

Case 28

Case 29

R. K., aged 8 years.
Type { Radius: simple, greenstick with angulation. Ulna: simple, greenstick with angulation.
Result: good anatomical, good functional.
Occupation: school.
Disability: 7 weeks.



Before After

Case 29

terior dislocation of the head of the radius. It is interesting to note that the entire group were free from serious complicating injuries. Good anatomical and good functional results were obtained in all cases and all had good union.

In the transverse and oblique fractures in this group (six cases), the average disability was over seven weeks, the shortest period being four weeks, while the longest, in the case of a laborer, was fourteen weeks.

The average disability for fracture of the coronoid process (six cases) was five and two-thirds weeks. The shortest period of disability for this type was three weeks; the longest, in a laborer before he could return to work, eleven and three-sevenths weeks.

Immobilization was in plaster. The fractures of the coronoid process were treated in acute flexion.

FRACTURE OF THE OLECRANON

In this group there were sixteen cases, or 3.8 per cent. of the entire series. Thirteen occurred in males, while three were in females. The right side was involved five times; the left, eleven times. The simple transverse type of fracture predominated, being present in eleven cases; followed by the simple comminuted, in two cases; and the simple oblique and compound comminuted in one case each. Eight cases occurred between the ages of twenty and forty years, while only four occurred before the age of twenty. Six cases presented serious complicating injuries. Fractures of the head of the radius were present in two cases. A fractured coronoid process, with a posterior dislocation of the elbow, complicated another. The humerus was broken in one case, while another had an injury of the brachial plexus. In eight cases the fragments were displaced and in eight there was no displacement. In seven cases the fragments were sutured with kangaroo tendon. One case which was classified as displaced referred to an accompanying posterior dislocation of the elbow rather than a displacement of the fragments of the olecranon.

Fractures in this region gave uniformly good results. Fractures of the non-displaced type were treated by immobilization in plaster, with the elbow at 90 degrees, and early motion; while in the displaced types the fragments were sutured. In one operative case the kangaroo-tendon knot failed to absorb and had to be removed a year and one-half later through a small incision.

Good anatomical and good functional results were obtained in all but two cases. In both of these, union with good position was obtained; the functional impairment was due in one instance to fracture of the head of the radius, which was resected, with a resulting limitation in extension of 15 to 20 degrees. In the other instance a brachial-plexus injury resulted in a loss of function of the muscles of the elbow.

Disabilities: The average disability in the cases with no displacement was five and one-seventh weeks; in those in which the fragments were dis-

placed and sutured the period of disability was seven and one-seventh weeks.

FRACTURES OF LOWER THIRD OF RADIUS AND ULNA (FIGS. 5-A AND 5-B)

There were thirty-nine cases in this group, constituting 9.4 per cent. of the entire series. Thirty-two occurred in males and seven in females. Thirty-one, or 79 per cent. of this group occurred before the age of twenty years (school age). The right side was fractured twenty-four times; the left, fifteen. The transverse type again predominated, being present in twenty-seven radii and twenty-eight ulnae. Next in order of frequency was the simple oblique fracture, occurring in four radii and three ulnae. In three cases there were greenstick fractures of both bones. Only one case presented a serious complication which lengthened disability. It is interesting to note that the fragments were displaced in thirty-four cases and required manipulative reduction. General anaesthesia was administered in thirty-three cases, and one with angulation was reduced without anaesthesia. Two cases required a second reduction.

Ordinarily reductions are not difficult, but occasionally one encounters difficulty in retaining the fragments in position. This is especially true in the oblique and comminuted types of fractures. In twenty cases plaster was used for immobilization, while in nineteen coaptation splints were used. When the latter were used, the elbow was immobilized with either a right-angle aluminum splint or a posterior plaster elbow splint.

Open reductions were necessary in five cases; in four of these the operation was on the radius; in one, on the ulna. The types of fractures requiring operations were two oblique, two transverse, and one comminuted. Silver wire was used as fixation material in one; the fragments were wrapped with fascia in another; kangaroo tendon was used in two; and one was treated by open reduction without fixation material. Four of the cases operated upon were below the age of twenty years.

Results:

(*a*) Good anatomical, good functional in thirty-five cases.
(*b*) Moderate anatomical, good functional, one case.
(*c*) Moderate anatomical, moderate functional, one case.
(*d*) Bad anatomical, moderate functional, one case.
(*e*) Bad anatomical, bad functional, one case.

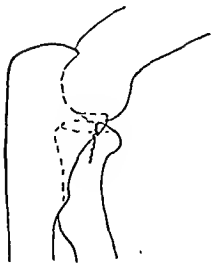
The result in the case designated *b* was very slight bowing. In the case marked *c* there was delayed union, arthritic tendencies, and incomplete restoration of function in the fingers. The impairment in the case *d* was angulation with interference of pronation and supination; and in *e* a marked deformity, the result of patient's negligence and a complicating fracture of the humerus (Fig. 5-B, Case 21).

Disabilities: The average period of disability in the cases operated upon was over ten weeks. The average disability of patients below the age of twenty years, excluding those in whom open reductions were done,

FIG. 7-A

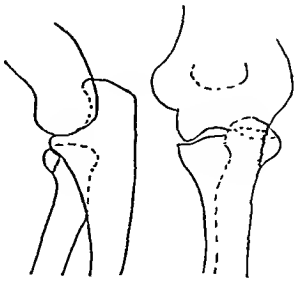
FRACTURES OF THE HEAD OF THE RADIUS.

Tracings from roentgenograms. Results with periods of disability.



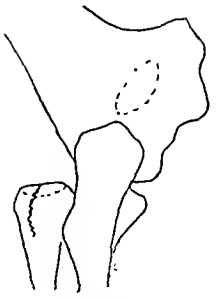
Case 30

M. T., aged 25 years.
Diagnosis: longitudinal fracture of head of right radius, not displaced.
Occupation: machine operator.
Result: normal function.
Period of disability: 3½ weeks.



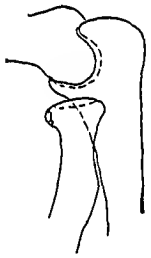
Case 31

Mrs. F. W., aged 48 years.
Diagnosis: longitudinal chip fracture, right, not displaced.
Occupation: housework.
Result: normal except limitation in extension of 10 degrees.
Period of disability: 6¾ weeks.



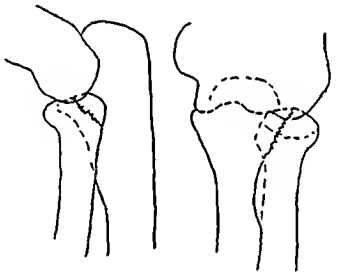
Case 32

L. W., aged 37 years.
Diagnosis: longitudinal fracture (not displaced), right, with lateral dislocation of elbow.
Occupation: farmer.
Result: normal except limitation in extension of 15 degrees.
Period of disability: 8 weeks.



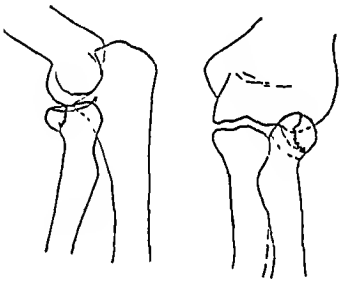
Case 33

Miss A. M., aged 25 years.
Diagnosis: chip of head of right radius, not displaced.
Occupation: nurse.
Result: normal.
Period of disability: 8 weeks.



Case 34

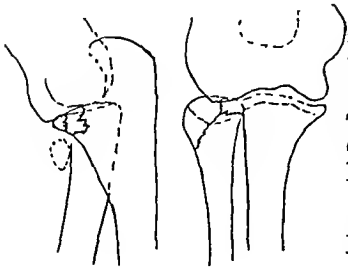
W. A. J., aged 21 years.
Diagnosis: oblique fracture of head, left, without gross displacement.
Occupation: fisherman.
Result: normal.
Period of disability: 10 weeks.



Case 35

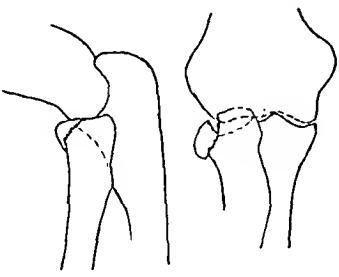
Miss B. H., aged 26 years.
Diagnosis: tearing fracture of the head of the right radius, involving the elbow joint, no displacement.
Occupation: stenographer.
Result: normal, except 5 degrees limitation in extreme extension.
Period of disability: 5 weeks.

Case 36



Case 36

A. D., aged 35 years.
Diagnosis: comminuted fracture head of radius, no displacement.
Treated conservatively.
Occupation: electrician.
Result: normal, except limitation in extension of 10 to 15 degrees.
Period of disability: 13½ weeks.



Case 37

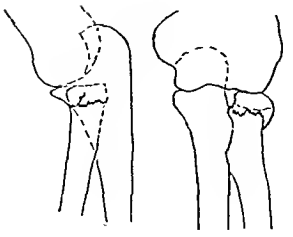
Case 37

Miss J. M., aged 32 years. Diagnosis: fracture of head, slight displacement. Occupation: beauty parlor operator. Complications: compound fractures of both patellae. Result: normal, except limitation in extension of 10 degrees. Period of disability: 6 months, due mostly to patellar injuries.

FIG. 7-B

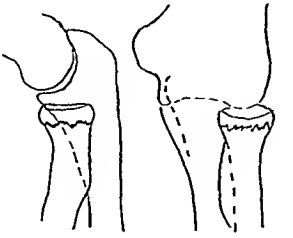
FRACTURES OF THE HEAD OF THE RADIUS.

Tracings from roentgenograms. Results with periods of disability.



Case 38

Mrs. B. F., aged 33 years.
Diagnosis: comminuted fracture of head of right radius, slight displacement.
Treated by closed method.
Occupation: nurse.
Complications: fracture head of left radius. (See Case 43.)
Result: limitation in extension of 20 degrees with crepitus over the head of the radius in pronation and supination.
Period of disability: 8 weeks.

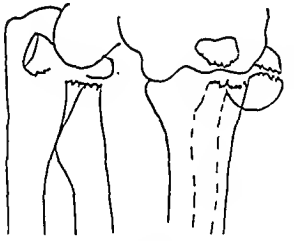


Case 39

J. K. C., aged 29 years.
Diagnosis: transverse fracture of head of left radius, not displaced.
Occupation: insurance salesman.
Result: normal.
Period of disability: 7½ weeks.

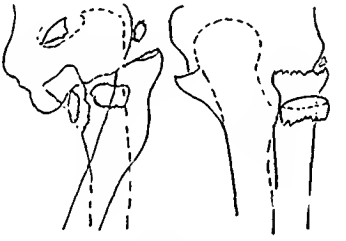
Case 40

Miss R. P., aged 32 years.
Diagnosis: comminuted fracture of head of right radius, displaced.
Reseeted early.
Occupation: housework.
Result: normal except limitation in extension of 15 degrees.
Period of disability: 10 weeks.



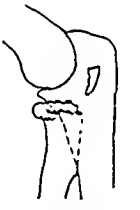
Case 41

A. B., aged 42 years.
Diagnosis: comminuted fracture of head of right radius, displaced.
Resection of head, late.
Occupation: laborer.
Complications: lung embolism.
Result: bad,—pain, extension limited by 15 degrees, flexion to 90 degrees. Marked impairment in pronation and supination.
Compensation case, with tendency to exaggerate.
Period of disability: 17¾ weeks.



Case 42

M. S., aged 43 years.
Diagnosis: comminuted fracture of head of left radius with marked displacement. Shaft of radius dislocated backward with fracture of lower end of humerus.
Resection at 3 weeks.
Occupation: furnace work.
Result: extension to 135 degrees; flexion to 55 degrees.
Pronation and supination 50 per cent. No pain.
Period of disability: 16 weeks from heavy duty.



Case 43

Mrs. B. F., aged 33 years.
Diagnosis: comminuted fracture of head of left radius, displaced.
Resection.
Complication: fracture of head of right radius. (See Case 38.)
Occupation: nurse, housework.
Result: normal, except slight limitation in extension of 10 degrees.
Period of disability: 8 weeks.

was over six weeks. The average disability of those below the age of twenty years, including the operative cases below that age, was seven weeks. The average disability of those above the age of twenty years (working class) was twelve weeks.

In all cases firm bony union was obtained, though in five cases union was not secured for over ten weeks. In two of these cases open reduction was necessary.

FRACTURES OF MIDDLE THIRD OF RADIUS AND ULNA (FIGS. 6-A AND 6-B)

This group comprised twenty-two cases, or 5.3 per cent. of the entire series. Eleven fractures occurred before the age of twenty; the cases were equally divided as to sex. The right arm was broken fourteen times; the left, eight times. Fifteen fractures were displaced and required reduction. Again the simple transverse type was the most frequent, occurring in twelve radii and in ten ulnae. The type next in frequency was the simple oblique fracture, occurring in five radii and in five ulnae; then the compound comminuted, in two radii and two ulnae; then the greenstick, in two radii and two ulnae.

Reductions become increasingly difficult in fractures of both bones as one ascends the forearm. This also applies to retention of the fragments in the corrected position.

In twelve cases coaptation splints were used, often in conjunction with interosseous pads, the elbows being immobilized in the manner previously described. In ten cases circular plaster casts were used. In the early cases of fractures of both bones of the forearm, the author used the position of extreme supination in order to preserve the interosseous space. This position has been discarded in favor of a position mid-way between pronation and supination, as the return of function is more easily accomplished from this position than from that of extreme supination.

No cases of radio-ulnar synostosis occurred in the series. In two cases open reductions were necessary. In one of these cases two operations were performed, the second being a step-cut operation shortening both bones. After three years, although the fragments are still in good position, no union has occurred in this case and the ends of the fragments are eburnated. This case was classed as a poor anatomical and poor functional result. It is necessary for the patient to wear a leather cuff continuously. In one other case a débridement was performed, followed by traction of the banjo type. In another case, with a small compound wound of the radius, malignant oedema supervened and an amputation was necessary. Union occurred in all cases with the exception of the one that was operated on twice.

Results in nineteen cases:

(*a*) Good anatomical and good functional, eleven cases.
(*b*) Moderate anatomical and good functional, four cases.
(*c*) Good anatomical and moderate functional, one case.

(*d*) Bad anatomical and good functional, one case.

(*e*) Bad anatomical and bad functional, two cases.

In reviewing the cases of the group *b* it was found that displacement was very slight and did not interfere with function. In the case classed as *c*, although a good anatomical result was obtained, there was slight impairment in function from prolonged immobilization. This was not sufficient to interfere with the patient's employment as operator of an oil still. In the case marked *d*, a boy of two years, the poor anatomical result was caused by angulation. He obtained a good functional result. In the group *e* one case already described had non-union of both bones, and the other a poor position of the fragments.

Disabilities: In nine cases below the age of twenty, the average disability was over five weeks. In eight cases above the age of twenty the average was over fifteen weeks. Union was delayed, in six cases, over fourteen weeks. In two of these, although the position was good, the delay was fourteen and sixteen weeks; in one with angulation, it was twenty weeks. In another, complicated with fragility of the bones, union occurred in nineteen weeks (Fig. 6-B, Case 27); and in two, one a compound oblique and another a simple comminuted, it occurred in twenty weeks.

FRACTURE OF UPPER THIRD OF RADIUS AND ULNA (FOUR CASES)

Unfortunately this group is not large enough for conclusions. All of these fractures occurred in males. The left forearm was broken three times; the right, once. Three cases had displacement and required reduction. Two had serious complications. One of these had a fracture of the head of the radius, with considerable loss of the soft parts about the elbow, injury to the median nerve, and a fracture of the lower end of the humerus. The other had a fracture of the head of the radius and also a fracture of the olecranon in which the fragments were displaced. In this case the head of the radius was resected and the olecranon sutured. Although a moderate anatomical result was obtained, there was considerable limitation in elbow motion. In all fractures of this group there was firm bony union.

Disabilities: In two cases before the age of twenty years, both uncomplicated, the average time lost was over six weeks. In two above the age of twenty years, both severely complicated, the average time lost was over fifteen weeks.

GENERAL CONSIDERATION

Union can be expected in most fractures of the forearm, providing the fragments are in good position and proper after-treatment is used. In three instances, or 0.7 per cent. of this series of 415 fractures, union was not obtained. One of these was a fracture of the lower end of the radius in a luetic, previously operated upon, which became infected following the second operation. Another was a fracture of both radius and ulna in the

middle third; the fracture of the radius was compounded, was twice operated upon, each time resulting in an eburnation of the fragment ends. The final result was failure, although the fragments remained in fair position.

Thirty-eight cases, or 9 per cent. of the total number, were treated by open reduction. Fifteen of these operations were resections of the head of the radius. The remaining twenty-three, or 5 per cent. of the total, were operated upon for the purpose of improving the position of the fragments or to stimulate union. All became firmly united, except in the three instances already described. The percentage of success in operative cases was 87 per cent.

Unlike fractures of the humerus, those of the forearm are not as often accompanied by injuries to the nerves. In this group only one case of nerve injury was encountered. This was in a fracture of both radius and ulna in the upper third, with injury to the median nerve, due to extensive loss of the soft parts on the anterior portion of the forearm just below the elbow.

Injury to the median nerve, as the result of a Colles' fracture or as the result of using the flexed position of the wrist to retain reduction, was not encountered. There were no cases of Volkmann's ischaemic contracture.

CONCLUSION

A review of the results of 415 fractures of the forearm has been presented. The cases were consecutive and give a fair picture of what may be encountered in such a series. Many interesting facts have been revealed, namely:

In most instances these fractures heal well, without residual physical disabilities, and the patients can return to their former occupations. The time lost varies with the location and nature of the fracture, complications, and the occupation and age of the patient. In children the healing is much more rapid than in adults.

The longest periods of disability have been in fractures of both bones in the middle, upper, and lower thirds, the middle third of the radius and the middle third of the ulna, and in late resections of the head of the radius. On account of the frequency of serious complicating injuries (19.4 per cent. of all cases in this series) due consideration must be given to them. Although operative interference was necessary only in the more severe cases, good results and good union were secured in 87 per cent. of the cases.

The length of time required in securing union in the cases operated upon was generally longer than in those treated by the closed method.

Fractures in the lower third of the forearm, comprising 66.7 per cent. of the total number in this series, heal rapidly and yield good results. This is especially true in the Colles' area, with the exception of the comminuted fracture which occasionally is still a real problem.

Fractures in the middle third of the forearm, 14.7 per cent. of the

total number, present more of a problem, as indicated by poorer results and longer periods of disability. These probably can be improved by better reductions and after-treatment.

Fractures in the upper third of the forearm, comprising 18.5 per cent. of the total number, are chiefly those of the olecranon and the head of the radius.

Displaced olecranon fractures are surgical problems and give excellent results.

In non-displaced fractures of the head of the radius, good results are obtained with conservative treatment. In displaced fractures in this location, early resections give the best results.

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THE END RESULTS OF THE FRACTURED DISTAL RADIAL EPIPHYSIS

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There have been but few reports in the literature on the end results of the separated distal radial epiphysis. Such reports as have been published are conflicting. Some writers state that a rather high percentage of these injuries end in deformity which is due to malposition of the displaced epiphysis, to retardation of growth, and to premature ossification of the epiphysis. It occurred to the author, while working in the Out-Patient Department of the Boston City Hospital, that he had not seen a single case of deformity following such an injury, although several hundred epiphyseal separations had been treated. Consequently, sixty patients have been examined and x-rayed, in whom the duration of the injury ranged from two to nine years. According to the literature, the deformity is usually apparent in from six months to one and one-half years, and becomes progressively worse. Thus the author has taken two years as the lower limit, feeling that the greater the length of time from the date of injury the more marked the deformity is apt to be.

In this series there were eight female patients and fifty male patients. The female patients varied in age from nine to sixteen years and the male patients from four to eighteen years. There were two cases in which the injury was bilateral. One was reverse in type,—*i. e.*, anterior displacement, with a chip off the anterior lip of the radial diaphysis. The posterior edge of the diaphysis was fractured in twenty-six cases, the ulnar styloid process in nineteen cases, and in twelve cases both these structures were fractured. In two cases the ulnar epiphysis also was displaced dorsally. There were seventeen cases in which manipulation was not attempted, the original position being considered satisfactory. At least one attempt at reduction was made in twenty-eight cases. In seven cases there were two attempts, while in four cases three attempts were made. There were also four osteotomies.

As this is the epiphysis from which the radius derives its main growth in length, we have been taught that accurate reduction of any displacement is essential; otherwise growth in the line of displacement would occur. Let us now consider what effect malposition has upon the ultimate alignment of the radius. In this series of cases, at the time when the patients were discharged from the hospital, the findings were as follows: normal to good position, twenty-six cases; slight displacement, twenty cases; fair to poor position, fourteen cases. If our teachings have been correct, we have then thirty-four cases in which we might expect some degree of deformity and this should be in direct proportion to the amount of displacement on discharge. However, in not one of these cases has there

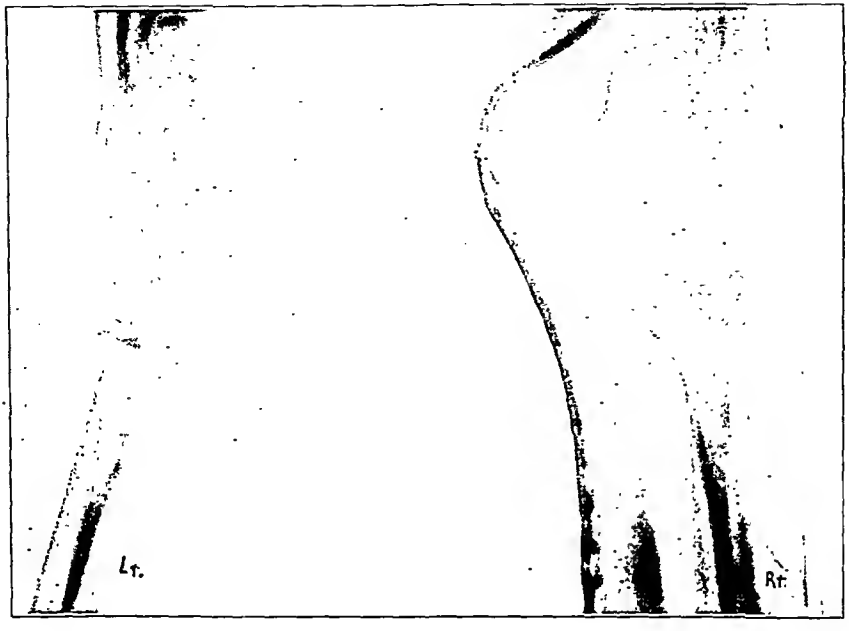

FIG. 1-A

C. B., aged 13. Bilateral displacement. Position on discharge: left—after one manipulation; right—after two manipulations and osteotomy (through epiphyseal line). All attempts to hold position failed. The cock-up splint was applied only temporarily. Note marked displacement of epiphysis, also marked amount of callus on dorsum of radius, extending up to the epiphysis.

FIG. 1-B

X-rays taken four years later. Note absence of any deformity. There was apparently no disturbance of growth on the right, although an osteotomy was performed directly through the growing cartilage.

been seen any form of deformity whatsoever, even in those cases in which the final displacement amounted to one-quarter to one-half of the thickness of the shaft. It is not definitely known how nature accomplishes this reduction. The evidence offered in Figures 1-A and 1-B seems to indicate that it is done by absorption of the volar portion of the shaft and the production of callus on the dorsum of the radius. The shaft is thus brought up into its normal relationship with the epiphysis. While this correction is in progress the normal volar bowing of the distal radius also becomes reestablished. In a few cases the lateral view shows some thickening of the entire lower end of the radius, varying from one-sixteenth to one-eighth of an inch. This, however, is the only evidence of injury that remains. These findings make one wonder whether the patient should be subjected to repeated manipulations, if, after one attempt, a fair degree of apposition is obtained. It also brings up the question as to whether an osteotomy is ever justifiable. It is the author's belief that it is not justifiable.

As to premature ossification and retardation of growth, there is no doubt that these phenomena do occur quite frequently. However, the difference in time of ossification between the radius and ulna of the same side or between the two radii is so slight that the amount of shortening must be measured in sixteenths of an inch. In only one case in this series has any radial shortening been detected clinically (Fig. 4). The patient did not notice it until it was called to his attention. He is a boy eleven years of age and it is now three and one-half years since his injury. His arm shows three-eighths of an inch of shortening. He has, however, about four to five years of normal growth ahead of him, so that if this deformity is progressive he may eventually develop some radial deviation of the hand. The interesting feature of this case is that the original displacement was slight and it required but one manipulation to correct it. Of the other cases, there were twelve in which there was retardation of growth, the maximum shortening being from three-sixteenths to five-sixteenths of an inch. In practically all of these cases ossification is now complete and clinically the condition is normal.

Still another interesting observation in regard to disturbance in growth is the fact that in four cases the radius on the injured side was actually longer than that on the uninjured side. In three cases this lengthening amounted to one-eighth of an inch, in the fourth to one-quarter of an inch. This increase in length is probably due to irritation of the epiphysis. This, plus the hyperaemia which occurs in all injuries, probably stimulates the epiphysis to more active growth.

Another question which has been brought up is whether or not repeated manipulations add to the damage done to the epiphysis. Of the four cases in which there were three manipulations, there is one-sixteenth of an inch of shortening in one case. Of the seven cases in which there were two manipulations, there is shortening in three cases of one-sixteenth, two-sixteenths, and five-sixteenths of an inch, respectively. In the

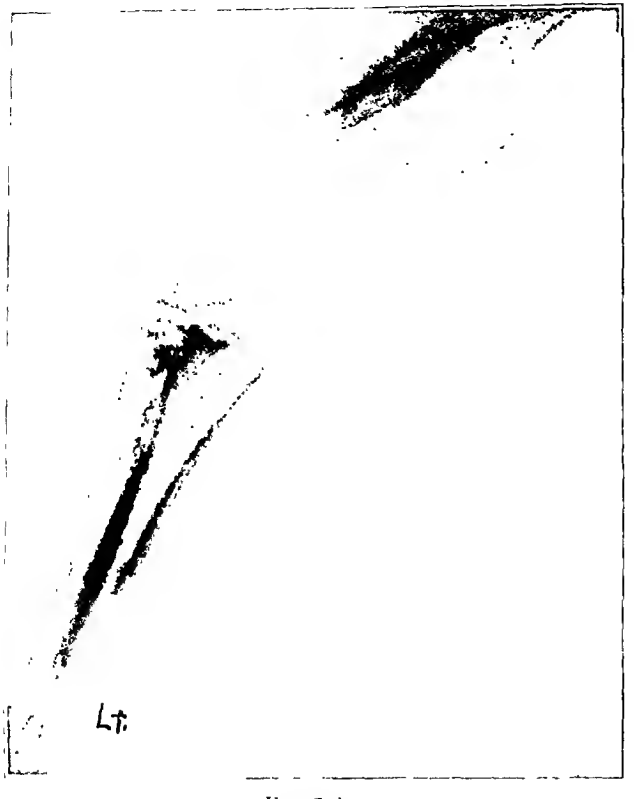

FIG. 2-A

J. K., aged 10. Position on discharge after three attempts at reduction.

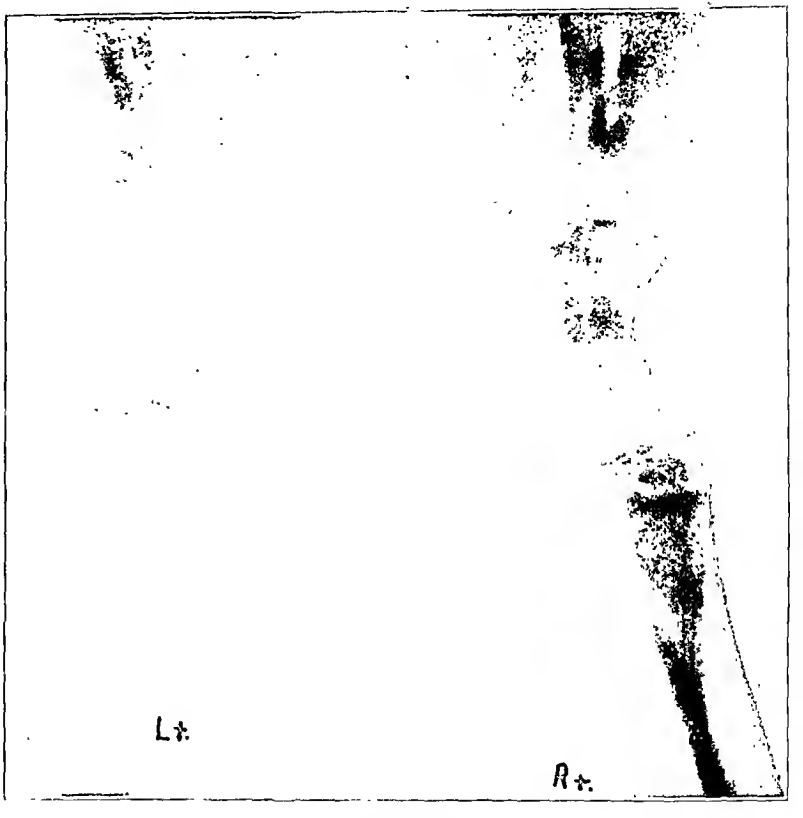

FIG. 2-B

X-rays taken five years later. Ossification not yet complete. Note that epiphysis has again assumed its normal relation to the shaft and that there is no deformity.

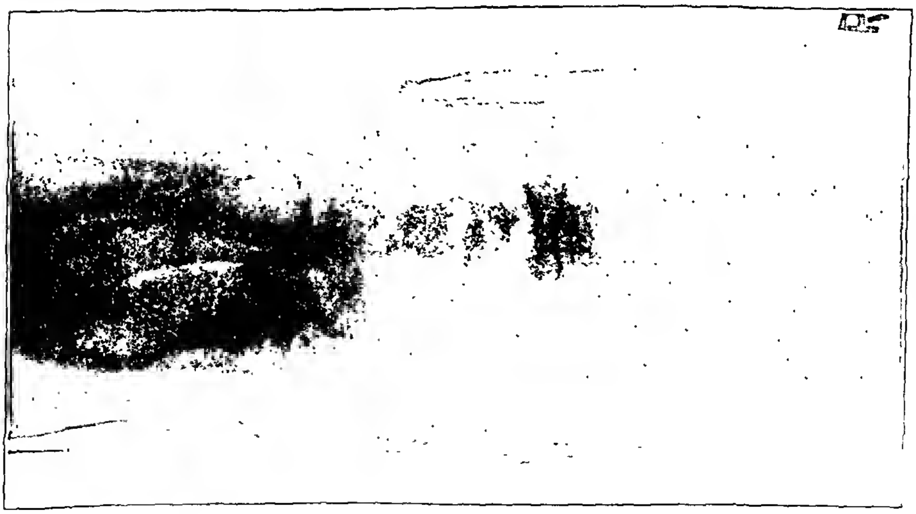

FIG. 3-A

J. G., aged 14. Position on discharge after one manipulation.

FIG. 3-B

Position five years later. Ossification complete. No evidence of any displacement remains.

latter case, as previously stated, ossification is nearly complete. Of the twenty-eight cases in which there was but one manipulation, there is shortening of from one-sixteenth to three-sixteenths of an inch in three cases. Of the seventeen cases in which manipulation was not attempted, there is shortening in four of from one-sixteenth to three-sixteenths of an inch. In one case, in which an osteotomy was performed directly through the epiphyseal line, there was no shortening. From this it can be seen that the occurrence of retardation of growth is as common in those cases in which there was no manipulation as it is in those in which one or more attempts at reduction were made. Manipulation, therefore, adds little, if any, trauma to the damaged epiphysis. Whatever damage is done occurs at the time of the injury.

FIG. 3-C

Anteroposterior view taken five years later. Note non-union and marked hypertrophy of the fractured ulnar styloid process.

The behavior of the concomitant fracture of the ulnar styloid process is also interesting. In all there were nineteen cases of this fracture. In two cases no styloid process whatsoever appears. In one case there is solid union to the shaft; in this case there was originally no displacement. In the remaining sixteen cases there was definite displacement of the fragment and recent x-rays show definite non-union in all of them. The detached styloid process becomes covered with cortical bone and assumes a more or less spherical shape. Rarely this fragment hypertrophies to such an extent that it blocks ulnar deviation of the hand and causes pain. In the entire series only three patients complained of any pain following their injuries; in all three cases the pain was over the ulnar styloid process and non-union and marked enlargement of the fragment were present.

Although we have had no cases of marked deformity in our series, several cases have been reported in the literature. These reports, however, lead one to believe that deformity is common following injury to the radial epiphysis. When we consider that this is one of the commonest injuries of childhood, the few deformities seen lead us to believe that only

FIG. 4

C. S., aged 8. Displacement of radial epiphysis three years previously. One manipulation was done. Now has three-eighths of an inch of shortening. Note V-shaped epiphysis. Retardation of growth is apparently occurring at the apex of the V, causing this portion of the epiphysis to drag behind. Note also the non-union of the fractured ulnar styloid process. Clinically, only a slight prominence of the distal ulna is discernible.

a very small percentage of the total radial epiphyseal injuries actually end in deformity. These poor end results are due, we believe, to severe crushing trauma received at the time of injury.

SUMMARY

1. Malposition does not persist. Within a maximum period of two to three years, the epiphysis has again assumed its normal relationship to the shaft. This fact obviates the necessity of repeated manipulation in order to obtain accurate reduction. It also eliminates the use of osteotomy for open reduction.

2. Premature ossification and retardation of growth occur frequently, but in the large percentage of cases are clinically negligible. There will always be the isolated case which will show definite interference of growth with deformity. This is due to damage done at the time of injury.

3. Ossification of the radial epiphysis apparently starts in the ulnar half of the epiphysis.

4. Repeated manipulation adds little, if any, to the trauma done to the epiphysis.

KÖNIG'S OPERATION IN THE TREATMENT OF CONGENITAL DISLOCATION OF THE HIP

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From the State Institute of Traumatology and Orthopaedic Surgery, Leningrad, F. I. Mashansky, M.D., Director

The authors dedicate this article to the honored memory of Prof. R. R. Vreden, the founder of Russian Orthopaedic Surgery.

It is beyond doubt that manipulative reduction is a most effective method in treating congenital dislocation of the hip, but it is quite evident that the employment of this type of reduction in all cases of congenital dislocation at an age most favorable for the success of the treatment is not possible. At the same time, in view of the dangers involved in the use of the radical reduction by incision in cases of resistant dislocation, it is easy to understand the keen interest shown in palliative methods of surgical treatment which have been described in a number of foreign and Russian papers.

Of these various methods, the following have been used in the Clinic of the late Prof. Vreden: (1) König's operation; (2) the v. Baeyer-Lorenz-Schanz operation; (3) the Veau-Lamy operation; and (4) arthroereisis of the hip joint after the method of Vreden.

This paper is limited to the description of König's operation.* In applying this procedure to dislocations of the hip, we do not, of course, expect to effect a radical cure. Our object is to do away with the phenomena invariably observed in this condition, among which Trendelenburg s symptom is the most prominent. The cause of this phenomenon is still under discussion.

We are led to conclude that the positive Trendelenburg symptom is due to the presence of two factors: the absence of normal muscular tonus—the insufficiency of the gluteus medius and the gluteus minimus; and the absence of a support against which the abnormally situated femoral head might rest.

It should be remembered, however, that, even if only one of the two components are present, the Trendelenburg symptom is always very pronounced. Thus, in cases in which the function of the gluteus medius and the gluteus minimus alone are disturbed—coxa vara, isolated paralysis of the gluteus medius and the gluteus minimus, dislocation of the hip in which the femoral head is fixed—the Trendelenburg symptom is always positive.

* The method has been used and modified by a number of surgeons: Hussenbauer, Schenborn, Kraske, Dickson, Gill and Wallace, Ferguson, Albee, Ellis Jones, Fairbank, Clarke, Delangénière, Lance, Mauclair, Dujarier and Hallopeau.

At present, we perform König's operation according to the following method:

As suggested by Prof. Vreden, the incision begins at the crest of the iliac bone and runs parallel to it, but at a somewhat lower level, until it reaches the anterosuperior spine, whence it is directed at an angle backward and downward, extending to about six centimeters below the apex of the greater trochanter. The attachment of the gluteus medius is dissected periosteally from the iliac bone through the archlike upper incision, while the anterior oblique incision serves to separate the anterior edge of the muscle from the muscles which are attached to the anterosuperior spine.

The entire cutaneous and muscular flap, together with the vessels and nerves, is turned down and backward, thus exposing the external lateral surface of the iliac bone from which is to be made the osteoperiosteal flap. This flap is cut in the shape of a fan by splitting the iliac bone into two separate layers by a cautious downward motion of the chisel. The flap is then gradually turned down by an oscillating movement. In pathological and pronounced congenital dislocations, the flap is not brought as far down as in paralytic dislocations in which the femoral head is readily slipped into the acetabulum. The flap, which is like a vizor in shape and is about six to seven centimeters in width in its broadest part at the top and somewhat narrower at the bottom, is fixed to the articular capsule by two or three catgut sutures along its free end. The muscular flap is then drawn over the vizor and sutured to the crest of the iliac bone and to the oblique muscles of the abdomen. Thus, after having been drawn over the osteoperiosteal ledge, the flap is brought back to its former position and sutured. During this procedure, the tension of the gluteal muscles is altered, for the points of their origin and those of their insertion are drawn further apart, a fact which contributes toward increasing their tonus during the postoperative treatment by massage and electrization and creates more favorable conditions for their functioning.

Thus, the operation deals with both the factors to which the development of Trendelenburg's symptom is attributed.

It should be noted that in cases in which the ledge is not brought into sufficiently close contact with the femoral head—when there is a definite gap between the ledge and the upper end of the dislocated femur—Trendelenburg's symptom does not completely disappear after the operation, even if the ledge is sufficiently marked. This is easily understood if we take into consideration the fact that König's operation is used in cases where the mobility of the femur along its axis is pronounced. Consequently, if the ledge proves to be situated at a certain distance from the femoral head after the operation, the femur must shift upward the distance which separates it from the ledge before it finds a purchase, which affects the patient's gait and results in his walking with a limp. In cases in which the ledge has not been drawn backward sufficiently, the femoral head may easily slip from under it even when the thigh is but slightly

flexed. Finally, it should be borne in mind that, in cases in which the shortening of the limb is considerable (over four or five centimeters), the tonus of the gluteal muscles is so far decreased, owing to the bringing into close proximity of the points of their origin and insertion, that it cannot be completely restored after the operation.

These considerations should all be taken into account before König's operation is employed.

König first suggested his method of operative treatment in 1891. He, himself, used this method only in the cases of two children, both of whom died of scarlet fever and diphtheria soon after the operation.

The total number of cases in which we have employed the procedure described is sixty-two; there were fifty women and twelve men. Of these, thirty-eight patients were operated upon in Prof. Vreden's Clinic at the Traumatologic Institute; the other twenty-four were operated upon at the Karl Marx Hospital, the Orthopaedic Department of the Institute for the Protection of Maternity and Infancy, and the Metchnikov Hospital.

The cases may be grouped according to age as follows:

Age Period	*No. of Cases*
Under 5 years	7
From 5 to 10 years	11
From 10 to 15 years	12
From 15 to 20 years	14
From 20 to 25 years	8
From 25 to 30 years	3
From 30 to 35 years	1
Total	56 *

* In six cases the exact age could not be determined.

According to etiology, these cases may be classified as follows:

Type of Dislocation	*No. of Cases*
Pronounced congenital	35
Pathological	20
Paralytic	6
Pronounced traumatic	1
Total	62

The following case reports show the results of this procedure as applied to the various types of dislocations.

PRONOUNCED CONGENITAL DISLOCATIONS

PATIENT S., a girl, aged ten years. Examination disclosed a congenital dislocation of the left hip, very pronounced Trendelenburg symptom, and mobility of the femur along its axis.

After an attempt at reduction by manipulation had failed, König's operation was performed by Prof. Vreden on December 14, 1932.

Four months later, the roentgenogram showed a distinct ledge over the head of the femur.

PATIENT I., a girl, aged twenty years, was admitted to the Institute suffering from a congenital dislocation of the left hip. When she was eleven years old an attempt had been made in a country hospital to treat her by manipulative reduction. The reposition was a failure. Several years later resection of the femoral head was done, also at a country hospital.

Upon admission to the Institute, examination revealed shortening of the affected limb of ten and five-tenths centimeters, a marked Trendelenburg symptom, and considerable mobility of the femur along its axis.

König's operation was performed by Prof. Vreden on March 3, 1932, and the femur was brought down two and five-tenths centimeters in the course of the operation.

A year later, the shortening of the limb was eight centimeters. The patient can now walk satisfactorily, but, owing to the considerable shortening of the limb still present, the complete disappearance of Trendelenburg's symptom could hardly be expected. The roentgenogram reveals a marked ledge over the femoral head.

PATIENT P., a boy, aged fourteen years. Examination disclosed a congenital dislocation of the right hip, shortening of the limb of six centimeters, pronounced Trendelenburg symptom, and mobility of the femur along its axis.

König's operation was performed by Prof. Vreden on September 23, 1931.

Nineteen months later there was no mobility of the femur along its axis and a complete absence of Trendelenburg's symptom. The patient was advised to wear an orthopaedic shoe. The roentgenogram (Fig. 1) reveals a well defined ledge.

PATIENT K., aged twenty years. Examination showed a congenital dislocation of the left hip, a marked Trendelenburg symptom, and mobility of the femur along its axis.

König's operation was performed by Prof. Vreden on March 13, 1924.

Nine years later the patient could walk very well, with no limp whatever. The roentgenogram (Fig. 2) reveals a strong ledge over the femoral head.

At first we believed König's operation to be indicated for the majority of cases of pronounced congenital dislocation, and employed it even in cases where the femoral head rested against the lateral surface of the iliac bone. At present, however, we use it only in those cases in which the mobility of the femur along its axis is manifest,—when the new acetabulum is absent, luxation is evident, and lordosis is not very apparent.

PATHOLOGICAL DISLOCATIONS

PATIENT P., a male, aged twenty-two, first complained of symptoms at the age of eight. Examination revealed fistulae in the region of the right hip, shortening of the limb of six centimeters, and mobility of the femur along the axis.

König's operation was performed on April 13, 1931. The roentgenogram (Fig. 3) reveals a well defined ledge over the femoral head.

PATIENT A., aged three and one-half years. Examination revealed shortening of the right leg of two centimeters and mobility of the femur along its axis.

König's operation was performed by one of us (G. J. E.) on March 3, 1925.

Eight years later there could be observed hardly any mobility of the femur along its axis and Trendelenburg's symptom was practically absent. The patient could walk very satisfactorily.

PATIENT I., a girl, aged seventeen years. She had suffered from inflammation of the left hip at the age of fourteen months. Examination disclosed shortening of the left limb of five and one-half centimeters, a positive Trendelenburg symptom, and consid-

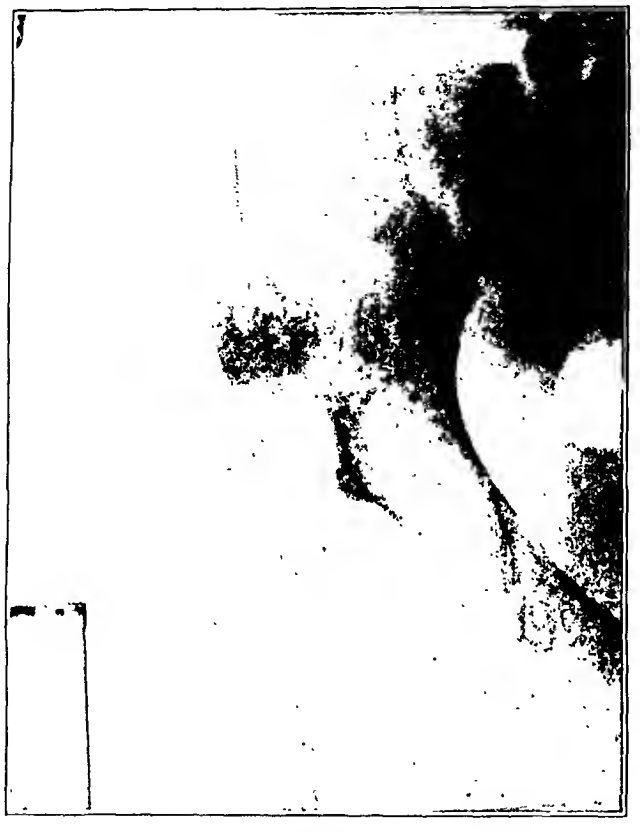

FIG. 1

Patient P., aged 14 years. Roentgenogram showing well defined roof over the femoral head.

FIG. 2

Patient K., aged 20 years. Roentgenogram showing strong ledge over the femoral head.

FIG. 3

Patient P., aged 22 years. Roentgenogram showing well defined roof over the femoral head.

erable mobility of the femur along its axis. Roentgenograms showed deterioration of the femoral head.

König's operation was performed by one of us (G. J. E.) on April 30, 1925.

Eight years later, the patient was able to walk very satisfactorily, and the roentgenogram revealed a strong ledge over the femoral head.

In this type of case, deformation of the femoral head and neck is usually observed. During the course of the disease, the old acetabulum becomes void and no new acetabulum is formed, owing to the lack of constant friction between the dislocated femoral head and the lateral surface of the iliac bone. This is frequently observed in cases of pronounced congenital dislocation of the hip.

FIG. 4

Patient R., aged 27 years. *Roentgenogram before operation.*

FIG. 5

Patient R., aged 27 years. Roentgenogram taken three months after operation, showing ledge which has been constructed over the femoral head.

From a study of the roentgenograms, in cases of pathological dislocation we usually observe excursion of the femur along the lateral surface of the iliac bone; the femur often forms a straight line with the remains of the neck and head. Under such conditions, it is hardly reasonable to expect a satisfactory result from such palliative methods of surgical treatment as, for instance, the operations of v. Baeyer, Lorenz, or Schanz. Even if the function of the gluteal muscles is improved, the object will not be achieved, owing to the absence of a support for the upper end of the femur against the iliac bone. In such cases, König's operation serves to prevent the femur from shifting along its axis and also increases the tonus of the abductors. Trendelenburg's symptom either completely disappears or becomes but slightly noticeable. The use of orthopaedic shoes enables the patients to walk very satisfactorily.

PARALYTIC DISLOCATIONS

PATIENT R., aged twenty-seven, had suffered from infantile paralysis since the age of three. Examination revealed laxity of the right hip and ankle. An attempt had been made to bring the femoral head down and insert it in the acetabulum, but the attempt proved to be a failure.

König's operation was performed by Prof. Vreden on February 27, 1933.

Three months later, the roentgenogram (Fig. 5) showed a very distinct ledge over the femoral head.

PATIENT B., aged sixteen years. Examination showed laxity of the left hip and ankle, and ankylosis of the left knee as the result of a previous operation.

König's operation was performed by Prof. Vreden in 1924.

At the end of seven months, the roentgenogram showed a distinct ledge over the femoral head. A more recent check-up has not been possible, as the patient is living in the country.

In cases of infantile paralysis in which all of the muscles surrounding the joint are involved, we employ König's operation. If the femoral head can easily be brought down and placed in the normal acetabulum, the operator's task consists merely in preventing future displacement of the head. By forming a vizor—a ledge over the femoral head—a powerful barrier is constructed, which serves to keep the head in place.

CONCLUSIONS

1. König's operation is indicated in cases of irreducible dislocation, characterized by the absence of lordosis and "*luxation plane*", and presenting mobility of the femur along its axis,—cases in which both of the factors causing Trendelenburg's symptom may be observed.

2. In cases of pathological dislocation, characterized by complete deformation of the femoral head and neck, where other palliative methods of surgical treatment can hardly be expected to produce the desired effect, König's operation permits the formation of a barrier which prevents the femur from shifting along its axis.

3. In cases of paralytic dislocation in which the femoral head has been brought down and placed in the acetabulum, the ledge formed by

means of König's operation serves to keep the femoral head from shifting upward.

4. In cases in which the shortening is very considerable (over four or five centimeters), owing to the bringing into close proximity of the points of origin and insertion of the gluteus medius and the gluteus minimus, the resultant loss of tonus can hardly be restored after operation; hence Trendelenburg's symptom does not completely disappear.

5. The osteoperiosteal ledge should be made as wide as possible, so that when it is turned down over the femoral head it is in the closest proximity to the upper end of the femur.

6. If possible, the ledge should be placed somewhat posterior to the dislocated femoral head to prevent the head from slipping out when the thigh is flexed.

7. The use of massage, electrization, and gymnastics in the postoperative period is of great importance in improving the function of the gluteal muscles.

The authors wish to express their gratitude to Dr. N. E. Berg, Dr. F. A. Kopylov, and Dr. T. M. Stepanov for their kind permission to use the material from their Clinics.

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ARTHRODESIS FOR TUBERCULOSIS OF THE HIP*

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It has been the experience of all who treat tuberculous joints that bony ankylosis is the most satisfactory result which can be obtained. No other result assures equal permanency of cure and freedom from late recurrences. It is a singular commentary upon our means of treatment that movement must be completely sacrificed in order to stamp out this low-grade infection. Nevertheless, it is true that a tuberculous joint which has finally become ankylosed definitely recovers from the infection and is in no further danger of future exacerbations of the disease. The truth is that our means of treating tuberculosis are limited and only feebly effective. In the last analysis, it is the patient himself who masters the infection. We have no specific drug, serum, or therapeutic agent, the use of which will quickly kill the organisms. We are restricted to the use of those agents which experience has proven of value for the enhancement of the patient's own powers of resistance. Of these only two are of any material value,—rest and sunshine. All successful measures for treating tuberculosis are based upon the principle of rest. Artificial pneumothorax and thoracoplasties for pulmonary tuberculosis, fixation by plaster and splints for joint tuberculosis, ileostomy to divert the faecal stream in tuberculosis of the colon, spinal fusion for Pott's disease, and excision of the tuberculous knee joint—all are applications of the principle of rest in the treatment of this disease. It may be accepted as axiomatic that, of all the agents at our disposal for the cure of tuberculosis, rest is the most important. The more complete the rest, the greater the likelihood of cure.

In the evolution of tuberculous joint disease, cure by spontaneous bony ankylosis is a rare occurrence. The much more common end result is subsidence of the infection, leaving the joint in a state of fibrous ankylosis. Such a joint, although it has some useful movement and seems free from infection, all too frequently contains latent organisms which can be stirred into renewed activity at a later date, often many years after the original infection seems to have subsided. Moreover, the time necessary to secure such a conservative cure is very long. The uncertainty of permanent cure and the time consumed in conservative treatment of hip-joint disease, contrasted with the better result obtained when spontaneous ankylosis occurs, invite the deliberate attempt to secure ankylosis by surgical treatment,—namely, arthrodesis.

* Presented at the Annual Meeting of the American Orthopaedic Association, Washington, May 9, 1933.

EXCISION OF THE KNEE JOINT FOR TUBERCULOSIS

In tubereulosis of the knee, the principle of arthrodesis is eommonly applied with conspicuous suecess. Excision of the knee for tuberculosis provides a rapid and nearly eertain means of cure. Experience with this treatment leads inevitably to the eonclusion that the saerifiee of movement is a priee well worth paying for the certainty of cure of a tuberculous joint. The applieation of the same prineiple to tuberculosis of the hip might be expected to yield similar results if bony fusion eould be obtained with eertainty.

ARTHRODESIS OF THE HIP

Technical Difficulties

Arthrodesis of the hip joint is beset by certain teehnical difficulties which have hindered the development of a satisfactory technique. The simple plan of removing articular eartilage from both joint surfaees, which works so satisfactorily in the knee joint, brings new technieal problems in the hip. Removal of the artieular cartilage makes the head smaller and the acetabulum larger, so that accurate fit and eontaet are lost. Looseness of the femoral head in the aeetabulum renders it impossible to maintain the denuded surfaces continuously in apposition with each other during the period in which fusion might be expeeted to oeeur. A further objection which has been raised against the intra-articular type of arthrodesis of the hip—namely, that it opens areas of aetive tubereulous disease—probably has not as much weight as might seem reasonable. As a rule, in the case of the knee joint, the frank opening of areas of aetive tuberculosis does not lead to disaster.

The teehnieal diffieulties involved in arthrodesis of the hip have led to the development of many ingenious operations. These may be divided into three groups:

1. The strictly extra-artieular operations in which the eapsule of the hip joint is not opened. In operations of this type some form of bone graft is used to build an extra-articular strut extending from the great trochanter to the wing of the ilium. Albee's bone strut and Wilson's iliofemoroplasty are the best examples of this group. The idea is attractive and the operations are meehanieally ingenious, but they have one important defect. The gap bridged by the graft is large and the grafts themselves are relatively small and weak for the purpose of bearing the whole weight of the body. Even when satisfactory fusion of the graft to the trochanter and ilium is obtained, fraeture of the graft all too frequently occurs during weight-bearing.

2. The second type of operation is a combined extra-articular and intra-articular operation. The head of the femur and the aeetabulum are denuded of cartilage and the diseased bone is removed back to cancellous bone of good quality. The intra-articular procedure is then reënforced by some form of graft stretching from femur to ilium. The operations of Henderson and Eikenbary are good examples of this type. Their im-

portant shortcoming is the lack of firm fixation during the period of fusion. The disproportion in size between the head of the femur and the acetabulum and the loose attachment of the graft deprive the joint of inherent stability and render difficult the attainment of that continued contact of bare bone which is necessary for fusion. No form of external fixation in the shape of a plaster spica, however carefully it may be applied, will completely abolish movement in the hip joint. Some movement is always possible within the plaster. If the patient is obese, this movement may be considerable. Operations for fusion of the hip joint should provide inherent stability which is more or less independent of external fixation.

3. Finally, there is the partly intra-articular, but chiefly extra-articular operation of which the operations of Hibbs and Ghormley are good examples. In these operations, the capsule of the hip joint is opened on its superior aspect, so as to expose the upper surface of the head and neck of the femur. Without disturbing the joint surfaces, a graft is implanted in the upper rim of the acetabulum and in the superior margin of the head and neck of the femur. In Hibbs's operation, the graft is taken from the upper portion of the shaft of the femur, including half of the trochanter. In Ghormley's operation, the anterosuperior spine of the ilium, together with a considerable portion of the adjacent wing, is used as a graft and is keyed into a slot. This type of operation is the most satisfactory yet developed. The gap bridged by the graft is small and to a considerable extent the grafts are self-locking, particularly in Ghormley's operation. More rigid fixation would be desirable.

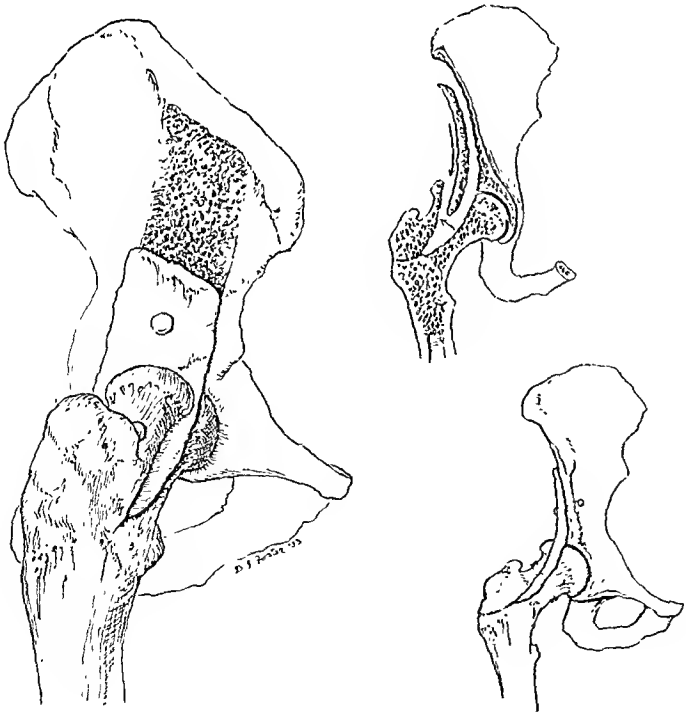

FIG. 1

Drawings illustrating the operation for arthrodesis of the hip described.

Requirements

In so far as the hip joint is concerned, the requirements for successful arthrodesis are: (1) an operation which shall be mainly extra-articular in order to avoid the difficulties attendant upon free opening of the joint; (2) a substantial graft of high osteogenic power in intimate and exten-

sive contact with both femur and ilium; (3) a small gap to be bridged by the graft; (4) firm fixation and maintenance of the graft in its bed until fusion has occurred.

AUTHOR'S OPERATION

The following technique has been slowly evolved to meet these requirements:

The hip joint is exposed by an adequate Smith-Petersen incision. The incision should extend from the junction of the posterior and middle thirds of the crest of the ilium to the middle of the anterior surface of the thigh. When the soft tissues have been raised subperiosteally from the wing of the ilium, this generous incision permits the whole of the soft tissues to be turned out as a flap, adequately exposing the whole anterior and superior surfaces of the hip. The capsule of the hip is then opened by a transverse incision along its anterosuperior aspect. The superior portion of the capsule is detached from the rim of the acetabulum and from the inner surface of the trochanter and turned backward (Fig. 1). With an osteotome, a large rectangular graft is then cut from the wing of the ilium immediately above the acetabulum. The graft must be large and strong and such a graft is not difficult to obtain. With an osteotome, the superior surface of the head and neck of the femur, as far out as the trochanter, is cut through and raised upward and outward, the trochanter acting as a hinge. The denuded surfaces of the neck and head of the femur and of the superior margin of the acetabulum and the wing of the ilium above it are then trimmed to form a continuous surface of bare bone onto which the graft can be slid downward to lie in accurate apposition throughout its whole length. A screw of bone transfixes the upper half of the graft through the ilium to the inner cortex. The flap from the upper margin of the head and neck of the femur is then laid back upon the lower half of the graft and is fastened with a long screw of bone which transfixes the cortex of the inferior surface of the neck of the femur. This results in such solid fixation of the graft to the ilium and to the femur that movement in the joint does not occur except by the application of considerable force. The wound is closed in layers and a long plaster spica is applied. The spica is maintained in place for four months.

Although this operation has been developed independently, it cannot be claimed that it is original. In many respects it resembles operations previously used. Nevertheless, it is a deliberate and carefully considered attempt to overcome the difficulties involved in fusion of the tuberculous hip. It provides accurate and wide contact between a graft of high osteogenic properties and the ilium and the femur. The gap bridged is small. Fixation is so firm that of itself it holds the structures firmly in the desired relationship to one another.

Results

The operation has been performed upon twenty-two patients ranging in age from thirteen to fifty-five years. Of the twenty-two patients, one

FIG. 2-A

FIG. 2-B

Mrs. B., aged forty-eight years, had tuberculosis of the left hip of thirty years' duration, with recent recurrence and abscess formation. At operation, the remnant of a large abscess was encountered. This was wiped out and the wall was excised. The wound healed by first intention. The hip is solid and painless.

Fig. 2-A: X-ray, December 1931, before operation.

Fig. 2-B: X-ray, January 1934, twenty-five months after operation.

died of a pulmonary embolus shortly after his operation and one is still immobilized in plaster. Of the remaining twenty, sixteen have solid bony fusion. In four cases the fusion is not quite solid, although the condition of the hip in each case has been much improved by operation. In two cases tuberculous abscesses in the field of operation were encountered, but this has not interfered with fusion. In one of these cases the wound healed by first intention; in the other case, a tuberculous sinus developed, which later healed. Satisfactory fusion resulted. In two other cases sinuses developed, presumably from exposure of active tuberculosis in the joint. In one of these cases, the screws were later removed as sequestra, but in both cases satisfactory fusion occurred and the sinuses are now healed.

FRACTURES AND DISLOCATIONS OF THE CERVICAL SPINE

BY O. C. HUDSON, M.D., HEMPSTEAD, NEW YORK

Forty-five cases of injury to the cervical spine, including all types of fractures and dislocations, were observed on the services of Dr. William L. Sneed and Dr. B. W. Seaman at the Nassau Hospital, Mineola, New York, from January 1, 1930 to January 1, 1934. A study of the x-rays was made possible through the courtesy of Dr. P. A. Williams and Dr. N. H. Robin of Hempstead, New York. The end results have been obtained in all but nine cases,—two patients are still under treatment and seven could not be located for follow-up examinations.

In this series, males were affected thirty-two times and females thirteen times. The ages varied from eleven to sixty-seven years. The greatest number of cases occurred in the decade from thirty-one to forty years of age.

The age incidence is as follows:

Ages	*No. of Cases*
1–10 years	0
11–20 years	5
21–30 years	4
31–40 years	16
41–50 years	13
51–60 years	5
Over 60 years	2

Occupation played no part in the causation of the injury, as shown by the following analysis:

Occupation	*No.*	*Occupation*	*No.*
Butcher	1	Toolmaker	1
Marble cutter	1	Janitor	1
Laborer	10	Housewife	12
Groom	1	Florist	1
Aerialist	1	Chauffeur	1
Salesman	5	Student	4
Plumber	2	Doctor	1
Retired	1	Policeman	1
Junk dealer	1		

Investigation of the causes of the injuries yields the following information:

Cause	*No.*
Automobile accident	20
Struck by an automobile	3
Struck top of automobile going over bump	2
Dove in shallow water	8
Rolled over by ocean wave	1
Fell from a hay loft	1
Fell from aerial horizontal bar	1

Fell from scaffold	1
Fell down flight of stairs	1
Fell out of swing, landing on head	1
Violent twist of head	1
Thrown from horse, landing on head	1
Struck by boom of crane	1
Struck head on limb riding horseback	1
Wrestling	1
Struck on head by bar, and fell hitting head	1

Injuries received while riding in an automobile or being struck by an automobile caused 50 per cent. of the injuries in this series; diving caused approximately 10 per cent.

The year incidence of the cases is as follows:

Year	*No. of Cases*
1930	11
1931	7
1932	14
1933	13

Site of Injury

The part of the cervical spine most frequently injured was the body of the vertebra. These fractures were of the compressed type. The fifth and sixth cervical vertebrae were most often injured. The transverse processes, odontoid processes, spinous processes, laminae, and pedicles were injured in the order mentioned. Dislocations frequently accompanied the fracture of the body of the vertebra, with fractures of the posterior arch. Four unilateral dislocations have been seen; such a dislocation can only occur between the axis and atlas.

The following table gives the sites of the lesions:

Site	*No. of Cases*
Compressed fractures of the body	23
Third cervical	1
Fourth cervical	6
Fifth cervical	7
Sixth cervical	8
Seventh cervical	1
More than one body involved	4
Fracture of the odontoid process	4
Fracture of the transverse processes	6
Fracture of the spinous process	3
Fracture of the laminae	3
Fracture of the pedicles	2
Unilateral dislocation between the axis and atlas	4
Multiple fractures	16
Fractures with dislocations	11

Treatment

The treatment in these cases was conservative. Traction with a halter, followed by the application of a plaster jacket, was used in all cases, except those in which the termination was fatal.

TABLE I

RÉSUMÉ OF THE FIFTEEN MOST SERIOUS CASES IN WHICH THE PATIENTS SURVIVED

Case	Cause of Injury	Neurological Signs	X-Ray Diagnosis	Treatment	Length of Treatment	Anatomical Result	End Result
1. H. W.	Dove into shallow water.	Present in upper extremities. Recovered.	Compressed fracture of fifth cervical vertebra, with dislocation.	Reduction and Calot jacket.	Eleven months.	Reduction incomplete.	Range of motion of less than 50 per cent.
2. P. H.	Thrown from horse, landing on head.	Present in upper extremities. Recovered.	Negative at time of accident. One year later evidence of old fracture of second cervical vertebra at base of odontoid process was revealed.	Application of Calot jacket, including head.	Five months and three weeks.	Good reduction.	Tenderness over first and third cervical vertebrae. Daily occipital headaches, pain on bending head forward. Unable to work.
3. R. A.	Dove into shallow water.	None.	Compressed fracture of seventh cervical vertebra.	Curved Bradford frame with twenty pounds of traction to neck for one week. Calot jacket for eight weeks. Leather collar for two months.	Four months and one week.	Good reduction.	Symptom-free. Practically a complete range of motion.
4. J. F. R.	Dove into shallow water.	Bladder distended. Recovered.	Compressed fracture of fifth and sixth cervical vertebrae.	Traction with head in hyperextension for eight days. Calot jacket for sixteen weeks. Leather collar for four weeks.	Eight months and eight days.	Good reduction.	Range of motion in neck of approximately 50 per cent., and gaining motion from time to time.
5. H. C. B.	Dove into shallow water.	None.	Compressed fracture of body of fourth cervical vertebra.	Calot jacket for eight weeks. Leather collar for sixteen weeks.	Six months.	Good reduction.	Range of motion of 70 to 75 per cent. in all directions in neck.
6. F. C.	Dove into shallow water.	Unable to move left hand. Recovered.	Compressed fracture of fourth and fifth cervical vertebrae.	Calot jacket for twelve weeks. Leather collar for three months.	Six months.	Good reduction.	Range of motion in neck of 50 per cent. No deformity or paralysis. Pain in neck after day's work or bad weather. Developed a traumatic arthritis of the cervical spine.
7. H. M.	Automobile accident.	None.	Compressed fracture of sixth cervical vertebra, with dislocation.	Calot jacket for four weeks. Leather collar for ten days.	Four weeks and ten days.	Good reduction.	At last examination, six months from time of accident, patient was free from pain. By personal communication two years later.

Case	Cause of Injury	Neurological Signs	X-Ray Diagnosis	Treatment	Length of Treatment	Anatomical Result	End Result
8. F. J. H.	Automobile accident.	None.	Fracture of the pedicle of the third cervical vertebra. Hypertrophic arthritis present.	Calot jacket.	Six months.	Good reduction.	Hypertrophic arthritis had increased at the end of one year. Grip was good. Reflexes all hyperactive. Considerable limitation of motion in neck, especially in flexion. Spasm of cervical muscles and tenderness present over the fourth to seventh cervical vertebrae.
9. E. C.	Automobile accident.	None.	Questionable malalignment of the fifth and sixth cervical vertebrae.	Patient violently and repeatedly twisted his head until a snap occurred in his neck and the pain was relieved. Refused further treatment.	None.	Normal appearing spine.	X-ray taken after patient twisted own neck showed no malalignment.
10. A. P.	Automobile accident.	None.	Fractures of the laminae and spinous processes of the second cervical vertebra, with some displacement.	Calot jacket for eight weeks. Leather collar for twelve weeks.	Five months.	Good reduction.	Recovered with no clinical symptoms and practically a complete range of motion in the neck.
11. T. D.	Dove through wave and struck head.	None.	Unilateral dislocation of right articular facet between first and second cervical vertebrae.	Under general anaesthesia a reduction was done and a Calot jacket applied. At end of six weeks an x-ray revealed recurrence of dislocation. Patient placed in bed with traction for twenty-four hours. This relieved pain. Another reduction was done under anaesthesia and a snapping was felt. Calot jacket was applied which was removed by patient at end of eight weeks.	Three months and three weeks.	Fair reduction.	After second plaster was removed by patient at end of eight weeks, he was quite comfortable and would permit no further treatment.

TABLE I (*Continued*)

RÉSUMÉ OF THE FIFTEEN MOST SERIOUS CASES IN WHICH THE PATIENT SURVIVED

Case	Cause of Injury	Neurological Signs	X-Ray Diagnosis	Treatment	Length of Treatment	Anatomical Result	End Result
12. R. P.	Fell out of swing, landing on head.	None.	Dislocation of left articular facet between first and second cervical vertebrae.	Under anaesthesia dislocation was reduced. Calot jacket applied and patient kept in bed six weeks. Leather collar then worn for four months.	Five months and two weeks.	Good reduction.	One year later patient had no symptoms and a complete range of motion in the neck.
13. R. W.	Turned head violently and suddenly to the left; something snapped.	None.	None taken before reduction.	Under anaesthesia by manipulation reduction was done and a snap was heard. On awakening, patient was free from pain and could move his head. Calot jacket applied for five weeks. Leather collar for three months.	Four months.	Good reduction.	Three months after injury, patient was symptom-free and had a complete range of motion in the neck.
14. A. W.	Automobile accident.	None.	Unilateral dislocation between atlas and axis on the right. Entire region of the atlas and odontoid obscured in the lateral view by extensive process undergoing calcification.	Patient placed in bed with twenty pounds of traction to head for seven days. Calot jacket applied and changed at end of six weeks. Kept recumbent for one month. Returned to bed for two weeks because of pain. New plaster applied for fourteen weeks. Leather collar for seven months.	Twelve months and three weeks.	Good reduction.	One year later patient was clinically free of symptoms. There was no tenderness or spasm of the cervical muscles. X-rays at this time showed normal relationship between the first and second cervical vertebrae, the lateral view showing considerable calcific deposits about the atlas in the region of the odontoid process.
15. C. D.	Automobile accident.	None.	Fracture of odontoid process and fracture of transverse process on the right of the seventh cervical ver	Calot jacket applied for eight weeks.	Eight weeks.	Good reduction.	Patient refused further treatment at the end of eight weeks. At this time there was moderate spasm pre and limitat on of

No operation was performed in any case of fracture of the cervical spine. It is believed that when permanent damage is done to the cord clinically, there is no hope offered by laminectomy. When the damage is secondary, the patient can recover the maximum power without the additional shock of an operation. Plaster Calot jackets were used for from twelve to sixteen weeks following injury and then a leather collar was applied for sixteen to twenty-five weeks more.

Length of Time in Bed

Patients with fractures of the spinous and transverse processes were not kept in bed if symptom-free. Patients with fractures of the laminae and pedicles were kept recumbent for four weeks.

In the simplest cases of compressed fracture of the body, the patients were kept in bed for four weeks; twelve weeks was the period of recumbency in the very severe cases where there was marked displacement. The average time that a patient was kept recumbent was eight weeks. Early in the series, one patient was allowed up too soon, with resulting loss of position and a poor end result.

Patients with unilateral dislocations of the axis and atlas were kept in bed for approximately four weeks.

Deaths

There were six deaths in this series. Three patients died within twenty-four hours of the accident; one died in forty-eight hours; and the other two died four days and nine weeks later, respectively. Five of the patients had a complete transverse myelitis from the time of the accident and one had an incomplete transverse myelitis. The patient with the incomplete lesion lived nine weeks and died of empyema following lobar pneumonia.

Neurological Symptoms

Objective neurological symptoms were present in ten cases. In five cases in which the termination was fatal, complete transverse myelitis followed immediately after the accident.

Patient T. B., who had an incomplete myelitis immediately following the accident, died. There was a paresis of all the muscles of the right lower extremity, with intense paraesthesia. There was paralysis of all muscles of both hands as well as weakness of the left triceps and supinator muscles.

Patient F. C. had a paresis of the left arm and hand shortly after the accident. Treatment by plaster splints was instituted with recovery in three months.

Patient H. W. had a paresis of the left arm and hand and right hand without sensory changes. Splints were applied and he recovered in two and one-half months.

Patient P. H. had an area of decreased sensation over both hands and forearms and a weak grip. He recovered.

Patient C. R. developed a complete paralysis of the right foot and leg twenty-four hours after the accident. Sensation had decreased over the right foot. He had retention of urine for six weeks. The right foot was splinted and recovery was complete in eight weeks.

End Results

The end results obtained in this series of cases are as follows:

Results	*No. of Cases*	*Per Cent.*
Unknown	7	15.56
Deaths (all due to compressed fractures)	6	13.33
Good	21	46.67
Fair	5	11.11
Poor	4	8.89
Under treatment	2	4.44

The end results with reference to the site of fracture may be tabulated as follows:

Good Results (46.67 Per Cent. of Cases)	*No.*
Fractures of the transverse processes	5
Fracture of the body (compressed)	8
Fracture of the pedicle	1
Fracture of the odontoid process	1
Fracture of the spinous process	2
Fractures of the laminae	1
Unilateral dislocation of the axis and atlas	3
Fair Results (11.11 Per Cent. of Cases)	
Fracture of the odontoid	1
Fracture of the body (compressed)	1
Fracture of the transverse process	1
Fracture of the pedicle and transverse process	1
Fracture of the odontoid process	1
Poor Results (8.89 Per Cent. of Cases)	
Fracture of the body	1
Fracture of the body and odontoid	1
Fracture of the body (compressed)	1
Unilateral dislocation of the axis on the atlas	1

DISCUSSION OF CASES

Case 1. This patient was allowed up too soon. If he had been kept recumbent for a long time, a better functional result would probably have been obtained. This case is one in which a spinal fusion, using either the Hibbs or the Albee technique, would have been better than the conservative form of therapy. It does not seem probable that a late spinal-fusion operation in this case would have reduced the permanent disability.

Case 8. The patient refused to remove the collar and was still wearing it spasmodically when seen one year later. As this is a litigation case and not yet settled, it is believed this plays a part in the patient's subjective symptoms. There has been a marked increase in the hypertrophic

arthritis since the accident, which could account for all the present symptoms.

Case 9. The exact pathology in this case could not be stated, although it is felt that the patient sustained a partial luxation of an articular facet.

Case 12. Before reduction, the patient had a left torticollis, and could move his head to the left, but not to the mid-line. After reduction and recovery from the anaesthesia, the patient stated that there was no pain and that he could move his head freely.

Case 13. It was impossible to get an x-ray before reduction as this fracture occurred on New Year's Eve. This is believed to have been a dis-' cation between the first and second cervical vertebrae.

Case 14. The attempt to change the plaster at the end of the six weeks caused a recurrence of all symptoms. The patient was then put to bed for two weeks, with rapid disappearance of all symptoms.

CONCLUSIONS

The usual fear of fatalities following injuries to the cervical spine is not warranted.

Cases of injury to the cervical spine with immediate cord damage and objective findings of a complete myelitis have a hopeless outlook for recovery.

Cases of injury to the cervical spine with no cord damage have an excellent outlook for recovery.

Cases of injury to the cervical spine with incomplete or delayed cord injury have a fair outlook and certainly will improve.

Conservative therapy offers the patient the best prospect for recovery with a maximum of motion.

Laminectomy has not been tried in this series of cases.

Operative spinal fusion has not been tried in this series of cases. Occasionally spinal fusion may be indicated in cervical-spine injuries.

Prolonged immobilization is the best form of treatment. This should be continued past the time when x-rays show an excellent callus formation.

Severe injuries and fractures of bone may be present without roentgenographic evidence of the lesion until the healing and callus have been developed.

Traumatic arthritis may develop after any severe spine lesion.

Reduction of unilateral dislocations between the first and second cervical vertebrae under anaesthesia is the method of choice.

INTRACAPSULAR FRACTURES OF THE NECK OF THE FEMUR

A Simple Method for Properly Placing the Bone Graft*†

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The following simple method was devised, primarily, because of a desire to accurately employ bone grafts in the treatment of recent intracapsular fractures of the femoral neck without doing an arthrotomy. The presence of an arthrotomy, however, does not detract from the usefulness of the method. The technique, briefly, consists of the use of a Kirschner wire (Fig. 1, *A*) to act as a pilot for a drill (Fig. 1, *D*) that is enabled to rotate around the wire by a small hole bored through the longitudinal axis of the drill. Except for the hole through its longitudinal axis, the drill is similar to the electric fraise burr in the Albee[1] bone mill.

Previous to the time when the method to be described was developed, a similar procedure was devised for accurately inserting the Smith-Petersen pin. While the technique was being perfected, a review of the literature revealed that Johansson[2] of Gotemberg, Sweden, had, in a preliminary report, already described essentially the same procedure. Since that time King[3], Henderson[4], Jones[5], and others have also employed the procedure. The methods of inserting the Kirschner wires were essentially the same. A fluoroscope or some type of anglemeter was recommended to facilitate directing the pilot wire. As an added guide, King[3] inserted a wire by fluoroscope parallel to the femoral neck and just posterior to it. A modified Smith-Petersen pin, with a hole through its central longitudinal axis, was generally used. The author employs the standard Smith-Petersen pin. A hole, large enough to easily admit the Kirschner wire, is bored in the head of the pin. The wire, after passing through the head, follows along in one of the channels formed at the junction of the flanges. The tendency for the distal end of the pin to deviate from the pilot wire is prevented by a metal ring, hanging inside of which is a small wedge that keeps the pilot wire pressed to the center of the channel. This ring is slipped over the distal end of the pin. As the pin is driven into place, the ring passes backward until it reaches the head; at this point the wedge above mentioned swings out of the channel on a hinge, and permits the ring to slip off over the head of the pin.

TECHNIQUE

The patient is placed on a fracture table, the fracture manipulated, and the extremity is brought into a position of internal rotation and

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FIG. 1

A. Kirschner wire which acts as a pilot for canalized drill.
B. Hemostat to prevent pilot wire from rotating with drill.
C. Dowel shaper of the Albee bone mill, used to drive drill at right angles to motor.
D. Drill, canalized by a small hole bored through its longitudinal axis to enable drill to rotate around pilot wire.
E. Neck of femur.
F. Electric motor.

abduction with the hip and knee slightly flexed. The manipulation, as Gaenslen[6] has suggested, usually includes manual traction with the thigh flexed 90 degrees to correct overriding of the fragments, and to extract any portion of the posterior capsule that may be torn and interposed between the fragments. Before taking anteroposterior and lateral roentgenograms to verify the reduction, a wire is laid on the thigh, or inserted in the soft tissues directly anterior to the neck of the femur; this facilitates the directing of the pilot wire in the next step of the procedure.

Following a satisfactory reduction of the fracture, a Kirschner wire is drilled with a Mathews[7] hand drill through that part of the femoral neck which is most suitable for a bone graft. A proper placement of the wire is facilitated by internally rotating the extremity 30 to 35 degrees. It has been noted that with the extremity in this position the neck of the

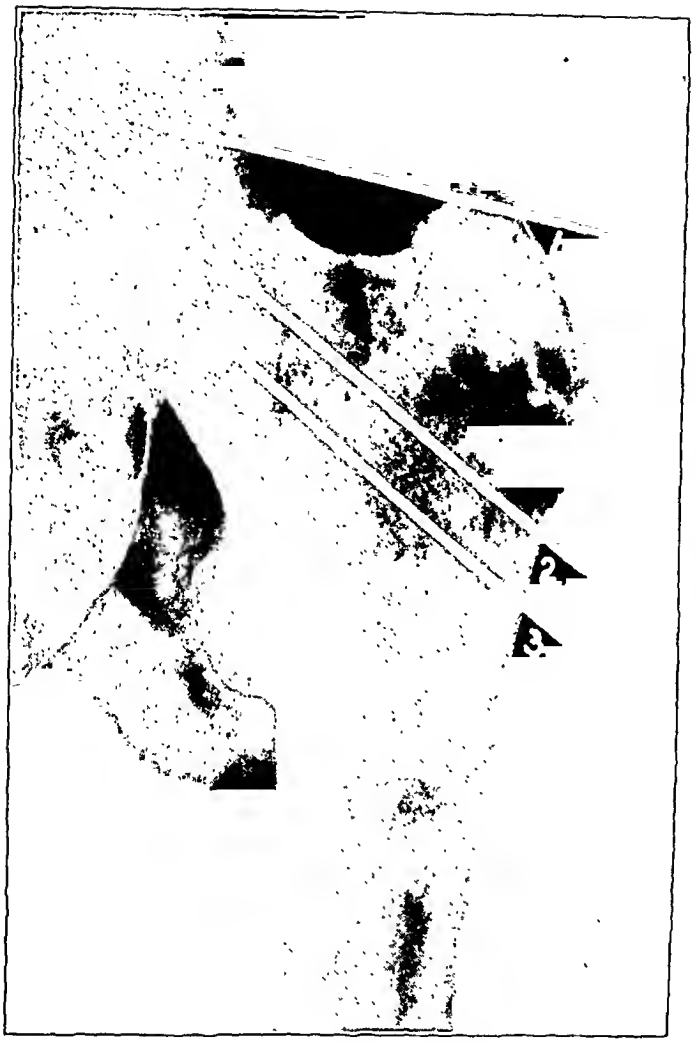

FIG. 2

Anteroposterior view after reduction of fracture and insertion of wires.
Wire *1:* Serves for fixation of head fragment to prevent rotation or deviation of this fragment.
Wire *2:* Used as pilot wire for drill.
Wire *3:* Withdrawn because wire *2* occupied the better position.

femur usually lies in a horizontal plane with the body. The wire should enter the shaft of the femur about one finger-breadth below the ridge from which the vastus lateralis muscle originates. This ridge forms the lower portion of the greater trochanter and is usually palpable. The wire is passed through the widest part of the neck by directing it upward at an angle about 10 degrees greater than the one which the neck forms with the shaft. Either a fluoroscope or an anglemeter may be used to more accurately direct the wire at this angle. By carefully following this course, the wire reaches the cortex of the head above the fovea centralis. This is desirable because the canalized drill, for which the wire is to serve as a pilot, will be directed above the blood vessels that enter and leave the head by way of the ligamentum teres. A second wire is inserted at a slightly different angle and position; then, following the check-up roentgenograms, the better placed wire of the two is retained as the pilot wire (Fig. 2, Wire *2*), and the other withdrawn (Fig. 2, Wire *3*). Another wire is inserted through the blunt tip of the greater trochanter and drilled straight in until it is well into the head fragment (Fig. 2, Wire *1*). This wire serves for fixation of the head, preventing rotation or deviation of this fragment when the canalized drill is used later.

The position of the wires should be checked by anteroposterior and lateral roentgenograms. Lateral views are indispensable in determining the exact position of the wires and fragments. The method described by

Johnson[8] would seem to be the most satisfactory for obtaining a true lateral view. The Johnson technique for taking these views is quickly mastered and requires no special equipment. Before taking a lateral view each wire must be individually marked. This may be done by the use of small lead rings or beads; the lead O's used in x-ray number plates serve well.

With the fracture reduced and the pilot wire and fixation wire accurately placed, the patient is taken to the operating room where the second half of the procedure is carried out. Up to this point the operation is conducted without employing a general anaesthetic.

FIG. 3

Position of fragments and wires in the lateral view.
Small lead rings are used to differentiate the wires in this view.
The lateral view is indispensable in determining the exact position of the wires and fragments.

An incision two inches long is made where the pilot wire enters the skin, and a small area of the femoral shaft is exposed where the wire enters the cortex. The canalized drill (Fig. 1, *D*) is set into the dowel shaper (Fig. 1, *C*) of the Albee[1] bone mill. The dowel shaper is used because it furnishes a means of rotating the drill at right angles to the drive shaft of the motor. This arrangement permits the lateral end of the pilot wire to protrude free from the end of the drill. When the drill is driven, the protruding end of the wire is held with a hemostat to prevent any possibility of the wire rotating with the drill and making its way into the pelvis. The drill is advanced the proper distance, as previously determined by measuring the roentgenograms and the depth of the pilot wire. The drill is then removed and the fracture site curetted. A small loop curette, bent to a right angle one-half

inch from its distal end, is directed into the drill hole until it reaches the fracture site. A Murphy two-prong rake retractor is hooked into the lower margin of the drill hole and the femoral shaft retracted laterally. This gives adequate distraction of the fragments to permit a curettement of the fracture site. The bone graft is taken in the usual manner. If a tibial graft is used, the cortical entrance of the drill hole is chiseled square to admit the bone graft which is one-half inch wide. After the graft is tapped into place, the fragments are impacted by a few blows on a short piece

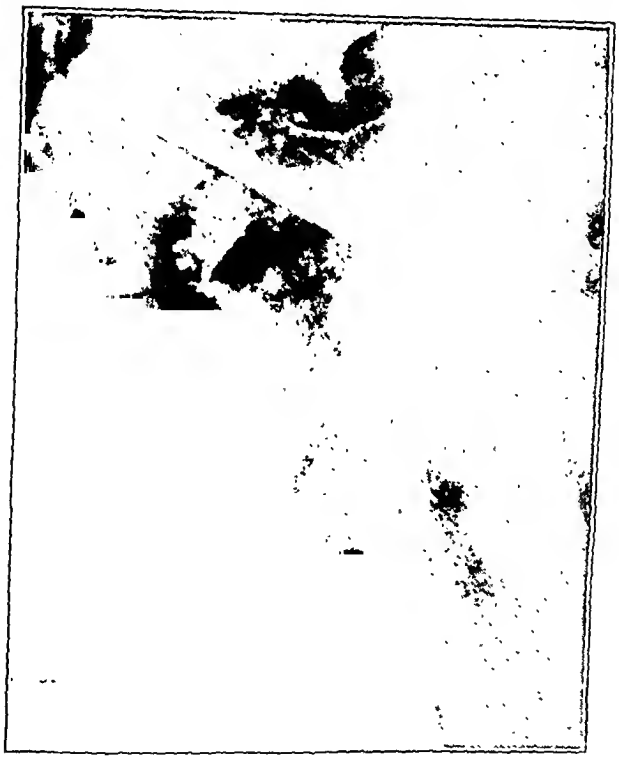

FIG. 4

Position of bone graft in anteroposterior view.

FIG. 5

Position of bone graft in lateral view.

of three-quarter-inch steel tubing, set against the femoral shaft adjacent to the drill hole. The operation is completed by closing the wound and applying a spica and a half cast.

In several of the cases operated upon thus far, it has been either inadvisable or inconvenient to do the operation promptly after the patient sustained the injury. In these instances the procedure has been to reduce the fracture and apply the cast; then, when the cast has dried, a window is made over the trochanteric region, through which the operation is performed when conditions permit. This variation in technique has proved very satisfactory.

In cases where an arthrotomy is done, the pilot wire is often inserted

more or less by direct vision. The extremity is externally rotated, and the fragment ends are thoroughly cleaned and freshened. Through a short lateral incision the pilot wire is inserted one or two centimeters below the lower border of the greater trochanter, and directed in, until it presents itself just superior to the center of the fractured surface of the shaft fragment. The extremity is then internally rotated, the fracture reduced, and the wire advanced until it reaches the cortex of the head fragment. The remainder of the procedure is as previously described.

Internal fixation is being used more and more in certain of the recent cases. In the cases operated upon thus far, the bone graft or Smith-Petersen pin has been placed with considerable precision, and there has been little or no evidence of shock. The results thus far are most encouraging. In a later communication an end-result study of the use of internal fixation in recent cases will be reported.

Since the canalized drill (Fig. 1, *D*) was devised two years ago, it has been used in fourteen cases, most of which were operated upon soon after the fracture was sustained. Of the recent fractures, an arthrotomy was done in only one instance; of the ununited fractures an arthrotomy was done routinely.

Since this paper was written, Macey and Henderson [9] have reported a case of an ununited fracture of the neck of the femur treated by a bone graft. At operation they used a procedure similar to the one employed by the author.

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INJURIES INVOLVING THE ILIUM

A New Treatment

BY S. A. JAHSS, M.D., NEW YORK, N. Y.

The utilization of the lever principle occurred to the author while treating a case of fracture of the ascending and descending rami of the pubes, with displacement.

The history of the case, symptoms, and physical findings are superfluous. The injury sustained was a fracture of the ascending and descending rami of the pubes on the right side, with displacement (Fig. 1).

TECHNIQUE

Heavy felt padding was placed at the proximal medial ends of the thigh, over the heads of the fibulae and the lateral malleoli. Both lower extremities were immobilized in plaster, from the groin to the toes, with the knees in complete extension and the feet at an angle of about 90 degrees. The receptors for the turnbuckles were incorporated in the plaster proper,—one set, which was superficial, near the groin; the other set, which was deep, at the lower part of the legs. The plaster was heavier at these points. The *greatest depth* of the *turnbuckle* was *exactly opposite* to the *direction* of the *force*. All the receptors were placed medially.

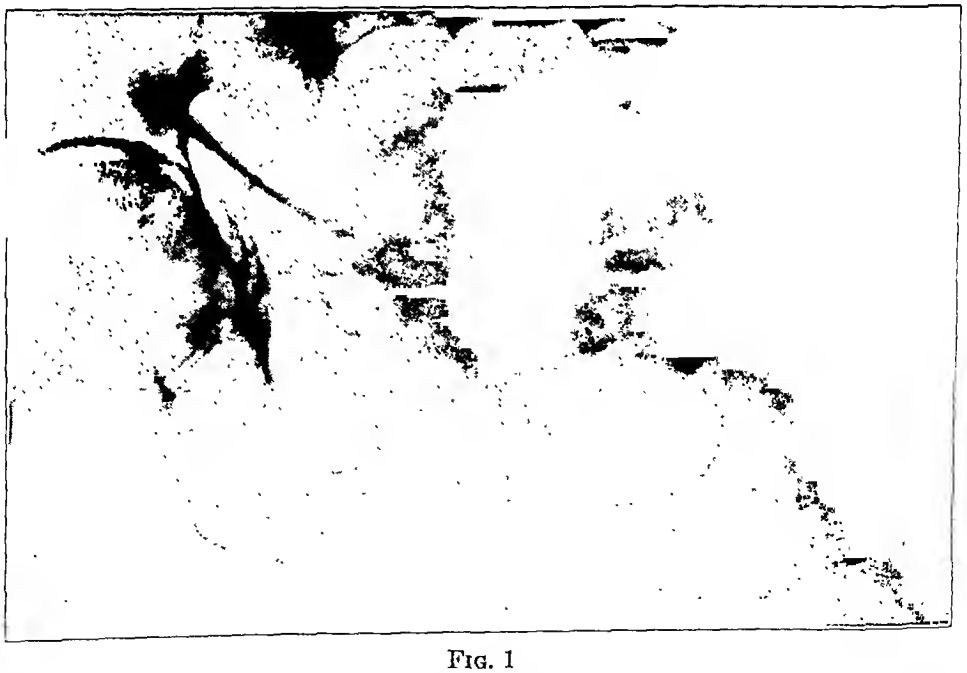

FIG. 1

Fracture through ascending and descending rami of pubes. Before reduction. Note the marked narrowing of the obturator foramen, due to the overriding of the fragments, and the break in the pelvic inlet.

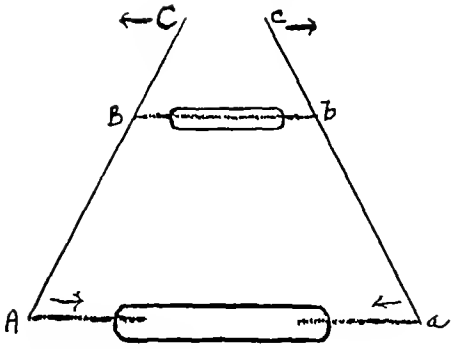

FIG. 2

Before reduction. Note the moderate abduction present.

AC and *ac*, lower extremities in plaster; *C* and *c*, groin, upper limits of plaster dressings; *Bb*, position of closed turnbuckle and position of fulcrum; *Aa*, position of open turnbuckle at lower part of legs.

Arrows show direction of effort, *Aa*, and of force, *Cc*.

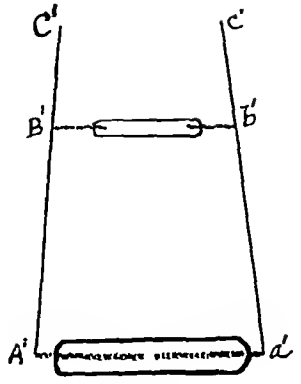

FIG. 3

After reduction. Note the distance between *C'* and *c'* as compared with *Cc* (Fig. 2).

After the plaster was absolutely dry, the limbs were moderately abducted. A closed turnbuckle was placed between the proximal receptors and an open turnbuckle, seventeen and one-half inches long, between the distal turnbuckles (Fig. 2). The closed turnbuckle was then slowly opened. This, of course, made the ligaments of the hip joints tense and tended to pull the pelvis open. (This was accomplished by the spreading of the upper ends of the plaster dressings which acted on the upper ends of the femora.)

FIG. 4

After reduction. Obturator foramen normal in outline. Note reestablishment of outline in pelvic inlet. Compare with Fig. 1.

The distal turnbuckle was then slowly closed. This was the *effort* end of the lever; the proximal turnbuckle acted as the *fulcrum only*. The force was applied at *C* and *c* (Fig. 3). (The direction of the effort and force is marked by arrows.) As a result of this action of the turnbuckles, the space between the upper ends of the thigh was widened and that between the lower ends of the legs lessened (Fig. 3).

The results of this leverage on the pelvis can be seen by a study of the roentgenogram (Fig. 4). Just how much force should be applied through the turnbuckles was problematic, but, in this case, the determining factors were the immediate relief of pain in the pubic region upon coughing or sneezing, and the correction shown in the roentgenogram.

The reduction itself can be accomplished in the short time necessary to open one turnbuckle and close the other.

FIG. 5

Note that the proximal turnbuckle is now open (originally closed) and that the distal turnbuckle is now closed (originally open); also how the upper and lateral parts of the plaster dressings are separated from the thighs proper.

The advantages of this treatment are:

1. Excellent realignment of the fracture is obtained.
2. The inlet and outlet regain their normal measurements.
3. There is immediate relief of pain.
4. The patient is able to sit up.
5. No soiling, etc.
6. No anaesthetic is required.

Realizing the possibilities of a broader utilization of leverage in the treatment of injuries involving the ilium, the author carried out an experimental study in the mortuary.

EXPERIMENTS

Central Fractures of the Acetabulum

A good part of the roof of the acetabulum was removed and the head of the femur was driven into the pelvis (Fig. 6). For reduction of this type of fracture, a very heavy proximal turnbuckle must be used. As soon as reduction has been accomplished (Fig. 7), the affected limb should be immobilized in a long plaster spica in a position of extreme abduction and full extension. The reason for applying a plaster spica is that so much force is required for reduction that the unnecessary discomfort due to stretching and pressure over a period of a few weeks would be both foolish and hazardous. The placing of the open and closed turnbuckles is the

FIG. 6

Before reduction. Head of femur in pelvis. Note close proximity of lesser trochanter to ischium. (Part of head of femur was unintentionally chiseled away while removing roof of acetabulum.) Note maceration of greater trochanter.

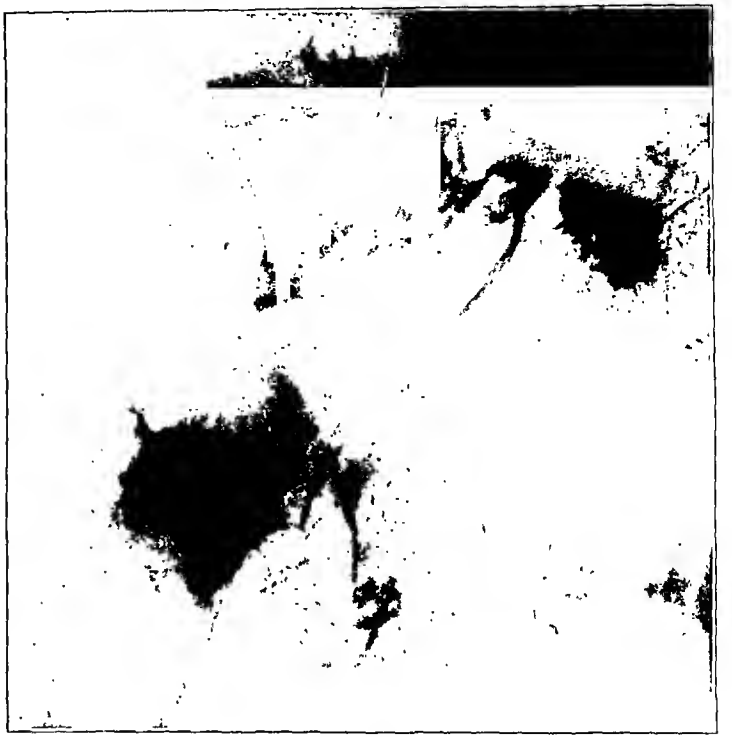

FIG. 7

After reduction. Note position of head of femur and lesser trochanter.

FIG. 8

Separation of symphysis pubes.

same as in pubic fractures, but the limbs must be very widely abducted (long turnbuckles).

Separation of the Symphysis Pubis

Since such splendid results have been obtained by a spreading of the pelvis, it was suggested that, should the work of the two turnbuckles be reversed, the heads of the femora would produce direct pressure on the acetabula and so bring the ilia together.

Heavy felt padding was placed over the greater trochanters and the medial malleoli. Plaster dressings were applied from the groin to the toes, the upper lateral limits of the dressings being the upper margins of the trochanters. The pubic arch was then dissected and freed, and a separation of the symphysis was produced (Fig. 8). The limbs were then slightly abducted; the open turnbuckle was placed medially and the closed turnbuckle was placed distally (Fig. 9). The proximal turnbuckle was then closed and the distal turnbuckle was opened (Fig. 10). The effect upon the separation can be seen in Figure 11.

Fracture of the Ascending and Descending Rami of the Pubes

Since it was desired to study further the *spreading* action of the treatment, the symphysis pubis was wired (there was no other cadaver available at the time) and an osteotomy was done through the ascending and descending rami of the pubes. Displacement was accomplished (Fig. 12) by lateral pressure, and the turnbuckles were reversed (a very long turnbuckle was placed distally). The proximal turnbuckle was completely opened and the distal turnbuckle was completely closed. As

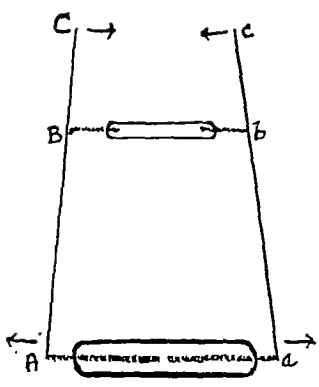

FIG. 9

Before reduction. Lettering same as Fig. 2. Here, the proximal turnbuckle is open and the distal turnbuckle is closed. Note wide space between upper ends of the thighs, due to separation of symphysis.

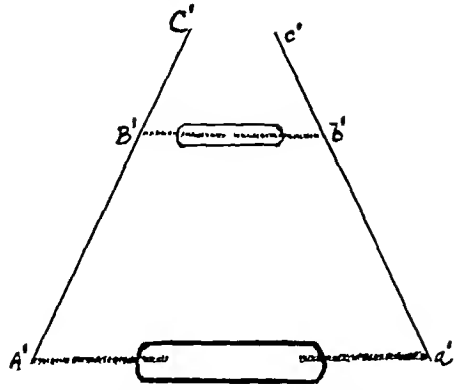

FIG. 10

After reduction. Note narrowing of space between upper ends of thighs (between *C'* and *c'*). Compare with Fig. 9.

a result, not only was the displacement overcome, but a separation of the fragments of between one and one-half and two inches took place (Fig. 13). The limbs were then flexed and extended, but there was no movement of the fractured ends. In other words, complete immobilization of the fracture was not affected by motion in the hips. This was also true after reduction of the separation of the symphysis pubis.

Further opportunity was afforded to test this method in the following case of fracture of the pelvis.

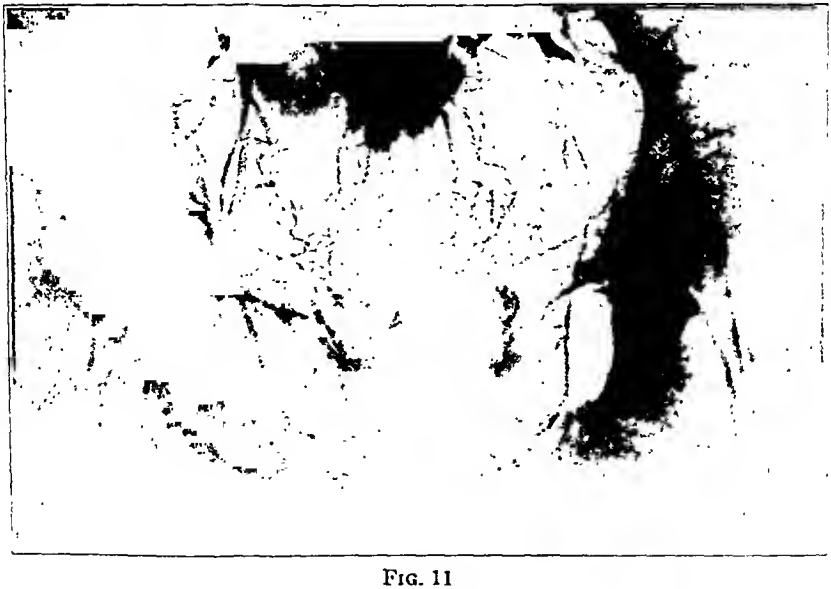

FIG. 11

After reduction of separation of symphysis pubes. (See Fig. 8.)

FIG. 12

Fracture through ascending and descending rami of the pubes. Note same displacement as in case actually treated (Fig. 1).

CASE REPORT

The patient was admitted to the Lenox Hill Hospital * in a semicomatose condition as the result of an automobile accident. The urine was tinged with blood. The patient developed a pneumonia of the right middle lobe and, for that reason, nothing could be done for his pelvic injuries until two weeks later.

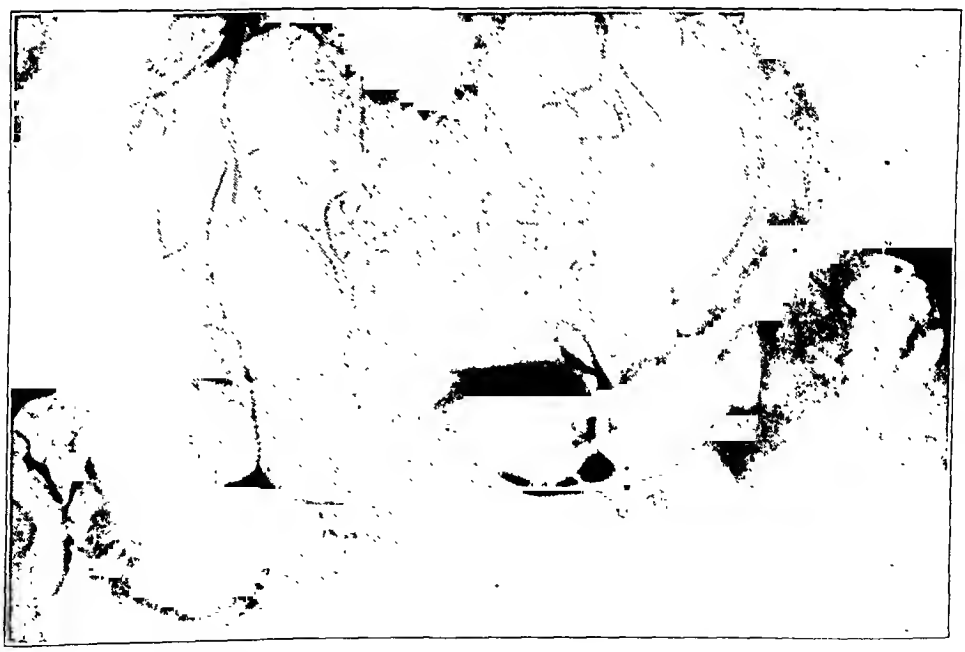

FIG. 13. Marked separation of fractured ends.

* Service of Dr. Otto Pickhardt.

A roentgenogram (Fig. 14), taken at this time, shows a comminuted fracture of the right ilium, pubes, and ischium, with marked displacement of the fragments. The head of the femur is displaced into the pelvic cavity proper and appears to be resting on the sacrum. The head of the femur has pushed the fragments ahead of it and is in such close contact with them that the normal joint space has been completely obliterated. The lesser trochanter is impinging on the ischium proper. The right pelvic cavity seems to be completely obliterated.

No thorough examination could be made because of the weak physical status of the patient and the severe pain present when motion was attempted. A concavity over the region of the greater trochanter could be seen quite easily instead of the convexity which is normally present. The greater trochanter could not be palpated.

Treatment according to the author's method was carried out.

. A roentgenogram (Fig. 15), taken a few minutes later, shows a complete reduction of the central displacement of the head of the femur and reestablishment of the normal joint space. At this time, a separation of the symphysis pubis could also be seen which was not visible before.

It is the author's belief that, although this separation appears to be of major proportions, it is far more apparent than real. The entire pubes with part of the ischium is greatly displaced laterally, obliterating the obturator foramen. It can easily be visualized that, should this fragment be reduced, the separation of the symphysis pubis would be almost negligible.

No anaesthetic, either local or general, was used.

FIG. 14

Before reduction. Comminuted fracture of the ilium, pubes, and ischium with marked displacement of the fragments. Head of femur apparently resting on the sacrum. No joint space. Obliteration of the right pelvic cavity.

FIG. 15

After reduction. Restoration of the hip joint and pelvic cavity.

SUMMARY

Based upon the results obtained in two actual cases and in three experiments on the cadaver, it is possible to obtain reduction of fracture of the pubes (ascending and descending rami), separation of the symphysis pubis, and central fracture of the acetabulum.

After being properly padded, each limb, from groin to toes, is immobilized in plaster in which are incorporated the receptors for two turnbuckles.

In the treatment of the pubic fracture, the limbs are moderately abducted and the open turnbuckle is placed *distally*, while the closed turnbuckle is placed *proximally*.

In treating the central fracture of the acetabulum, the limbs are widely abducted and the turnbuckles are placed in the same way as for the pubic fracture.

For the separation of the symphysis pubis, the limbs are slightly abducted and the open turnbuckle is placed *proximally*, while the closed turnbuckle is placed *distally*.

Much of the force of the leverage was lost, as the limbs tended to go into a position of external rotation. To combat this, two turnbuckles are now placed proximally,—one anteriorly and one posteriorly, the posterior turnbuckle being used as a derotator.

The author is greatly indebted to Dr. Walter I. Galland who treated the case reported.

BACKWARD DISPLACEMENT OF THE FIFTH LUMBAR VERTEBRA: AN OPTICAL ILLUSION

BY THEODORE A. WILLIS, M.D., CLEVELAND, OHIO

Notwithstanding reversal of social and economic beliefs by an alliterative political administration, nature's law of gravity still holds. Water doesn't, of its own accord, run up hill; nor does a stalled motor car coast in that direction. To the discomfiture of the writer these facts were recently impressed upon his skeptical mind, and optical illusions will always be a part of his memories of the Wyoming mountains. Still brooding over the financial losses occasioned by the above experiences, he was immediately intrigued by recent descriptions of fifth lumbar vertebrae subluxating up the steeply inclined surface of the sacrum. Where was the illusion here?

In all discussions of backward luxation of fifth lumbar vertebrae, the diagnosis of this lesion has been based on the relation of the posterior border of the lower articular surface of the last lumbar vertebra to the posterior border of the upper surface of the sacrum. Though in the illustrations offered in proof of such displacements the former border is shown to be posterior to the latter, the anterior borders of these same surfaces seem to be in normal alignment. Measurement of the opposed lumbar and sacral surfaces in these illustrations reveals the secret of the illusion. In every instance the anteroposterior diameter of the sacrum is less than that of the last lumbar segment. While the anterior borders are in alignment, the posterior borders overlap.

To determine whether or not there is a normal difference in depth of the opposing lumbar and sacral articular surfaces, these were measured in fifty consecutive skeletons in the catacombs of the Hamann Museum. In only seventeen were they found equal. In thirty-three the anteroposterior diameter of the sacral surface was from one to four-sixteenths of an inch less than that of the opposing lumbar surface. Analysis of these surfaces showed the difference in anteroposterior depth to be due to the conformation of the posterior borders of the sacral surfaces. These varied from convexity to concavity toward the neural canal, while the posterior lumbar borders were regularly convex. The illusion of posterior displacement of the lumbar segment, then, can be attributed to relative shortening in anteroposterior diameter of the first sacral segment (Figs. 1-A, 1-B, and 2).

Two tracings were made of an illustration in a recent essay describing this "displacement". These were superimposed with the posterior borders of the lumbar and sacral articular surfaces aligned. There was then a definite overhang of the anterior lumbar border (spondylolisthesis?), and the sacral articular facets were behind the lumbar (Fig. 3).

There has been a minor disagreement as to whether or not the angle

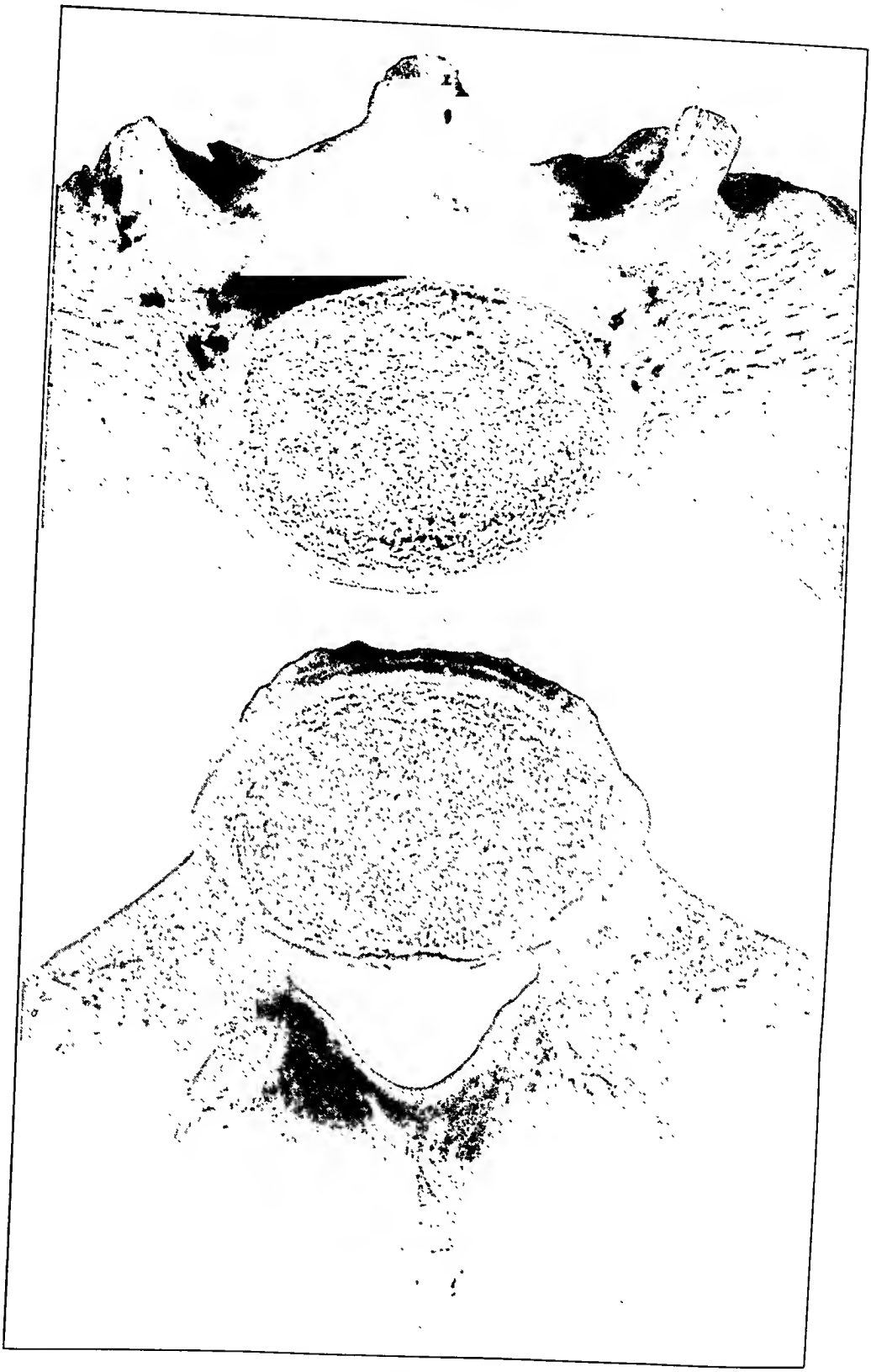

FIG. 1-A

Photograph of the superior surface of the sacrum and inferior surface of the last lumbar vertebra of skeleton 1182. Note convexity of the posterior border of the sacral surface.

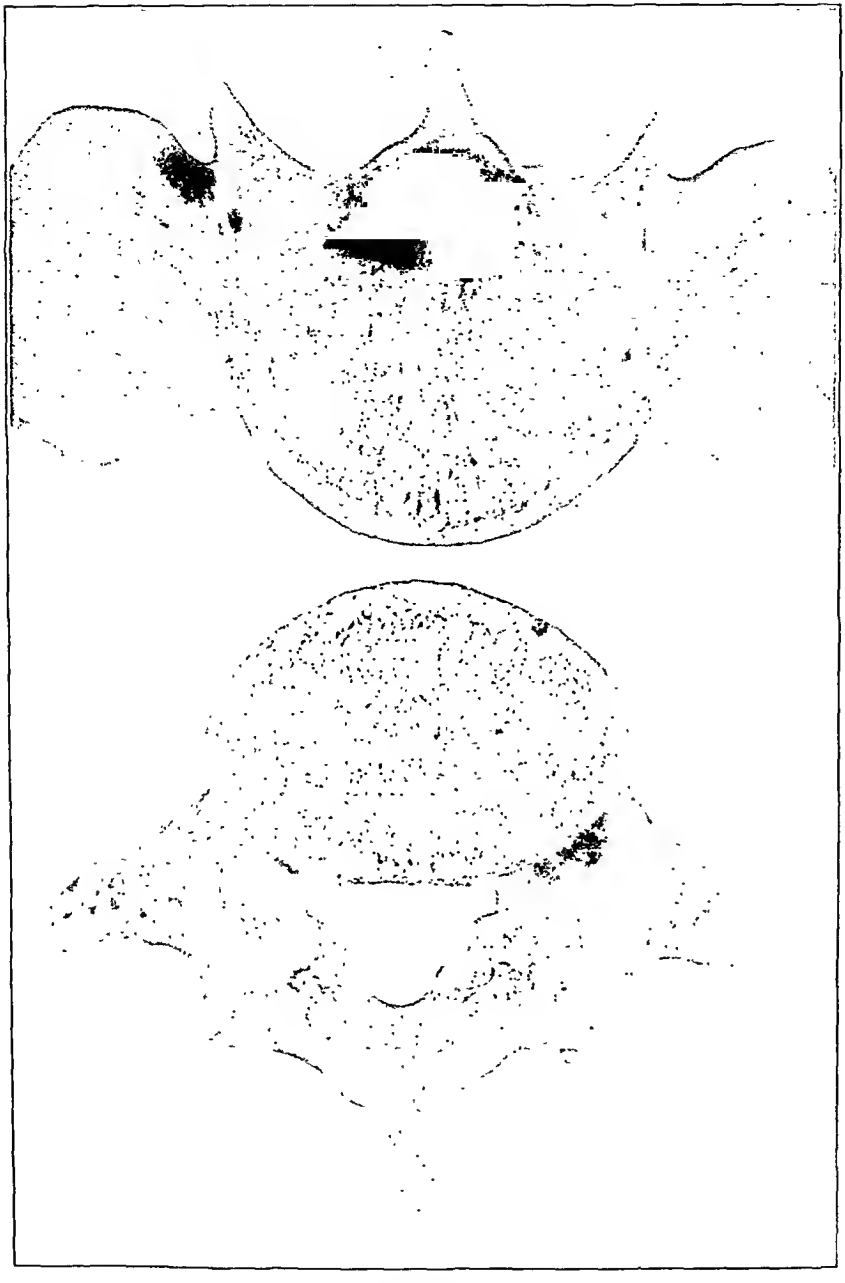

FIG. 1-B

Photograph of the sacrum and last lumbar segment of skeleton No. 1097. Note concave posterior border of the sacral surface.

from which a roentgenogram is made is of importance in demonstrating the "displacement". Naturally, if the skeleton chosen for a model is of the 34 per cent. having equal opposing last lumbar and first sacral surfaces, no

view will show a discrepancy. But if, by chance, the model is one of the 66 per cent. of skeletons having unequal anteroposterior diameters of these surfaces, the x-ray, to show the discrepancy, must be so directed that it will outline the most posterior portions of the two segments (Fig. 4).

Johnson[1] found the amount of "displacement" in twelve patients to vary between 0.3 centimeters and 0.7 centimeters, which is from slightly less than one-eighth of an inch to slightly more than one-fourth of an inch. He believes that the condition exists in at least 10 per cent. of patients with back symptoms. Smith[2] found the overlap to vary from one-eighth to one-fourth of an inch, except in two patients where it was, respectively, five-sixteenths and seven-sixteenths of an inch. He also believes that the lesion is quite common.

FIG. 2

Lateral roentgenogram of last lumbar vertebra and sacrum of skeleton 1097. When only the posterior borders of their opposing surfaces are considered, there appears to be a backward displacement of the lumbar segment on the sacrum.

Of fifty consecutive museum skeletons the diameters under discussion were equal in seventeen (34 per cent.). In the remaining thirty-three (66 per cent.), the sacral diameters were from one-sixteenth to one-fourth of an inch shorter than the lumbar, four of them reaching the latter figure.

It seems, then, that careful measurement of the bones in unselected skeletons demonstrates a difference in anteroposterior diameter six times as frequently as does the lateral roentgenogram in patients having back symptoms,—this in

spite of the fact that the latter, with the tube thirty-two inches and the sacrum eight inches from the film, magnifies the discrepancy by 25 per cent., making one-fourth of an inch difference of the bone surfaces five-sixteenths of an inch on the film. Apparently variations of less than one-eighth of an inch on the film are not noticeable.

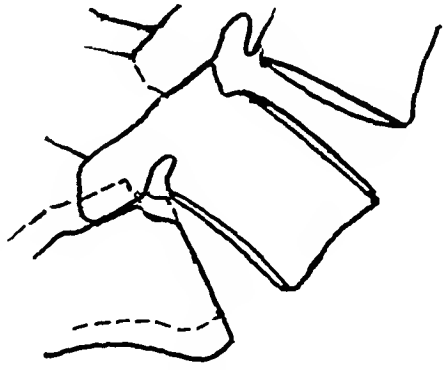

FIG. 3

Tracings of an illustration of backward displacement of a fifth lumbar vertebra (Smith—Fig. 5). Broken line shows position of the sacrum when the posterior lumbar and sacral borders are aligned.

Considerable importance in the production of the displacement, and of associated symptoms, has been attributed to downward and backward movement of the fifth lumbar articular facets. Since the transverse axis of lumbosacral flexion and extension is considerably anterior to the facets, this downward and backward movement, as well as "wedging" of the lumbosacral intervertebral disc, is simply a part of extension of this joint. Habitual extension of any joint gives rise to symptoms of chronic strain, which no doubt can be relieved by fusion of the affected bones. Thus Smith finds that while the "displacement" was unchanged, except in one patient, after fusion, the pain was relieved in all but one of the nineteen cases operated upon. The pain then could not have been due to the displacement itself. The operation eliminated the supporting rôle of ligaments and muscles, and it is reasonable to suppose that, in the absence of diseased tissue, pain relieved by this means had been caused by undue strain upon these structures.

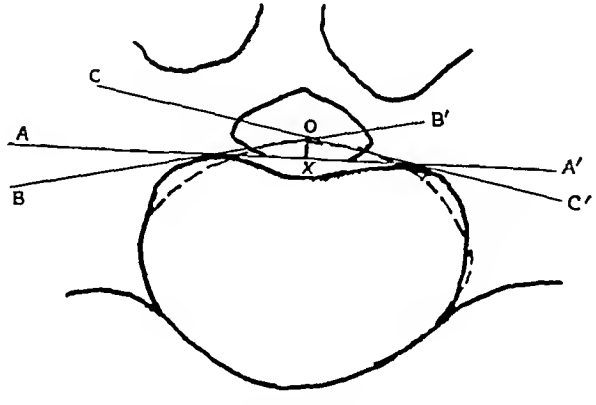

FIG. 4

Tracings of Photograph of 1097 (Fig. 1-B). Solid line is the upper surface of the sacrum. Broken line is the inferior surface of the last lumbar vertebra. *OX* is the distance by which, in a straight lateral roentgenogram, the lumbar segment would appear to be posteriorly displaced on the sacrum (see Fig. 2). This distance would decrease as the tube moved either forward or backward from the straight lateral position, disappearing entirely when the angles *COB* or *C'OB'* were passed.

Though this so called displacement has not been held directly responsible for low back pain, the two have been very definitely associated. Actually the differ-

ence in anteroposterior diameter of the last lumbar and first sacral bodies is due to eneroachment of the neural canal upon the bodies. As the posterior elements of the saeral vertebrae fuse behind the canal, the latter approximates the fused sacral bodies, hollowing out their posterior surfaces.

As a rule the first sacral segment is convex posteriorly, but less so than the last lumbar. The second and lower saeral segments are usually concave. In some individuals the first sacral presents this eharacteristie of the second. It is, then, another of those lumbosaeral anomalies assoeiated with numerieal variation of vertebrae. Beeause it is found no more frequently in painful backs than in museum skeletons, it is probably of no clinical importanee, and is eertainly not to be considered a displacement.

The writer is indebted to Dr. T. Wingate Todd, Professor of Anatomy and Director of the Hamann Museum, for access to the material and use of the facilities of his Department.

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SEPARATION OF THE CAPITAL FEMORAL EPIPHYSIS

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From the MacAusland Orthopaedic Clinic

The lack of end-result studies in literary contributions on the subject of slipping of the capital femoral epiphysis, and the question of the efficacy of the closed reduction in treating this lesion, induced the writer to review the series of cases that have been treated at the MacAusland Clinic. During the past twenty-two years, forty-five cases of slipped epiphysis of the upper femur have been seen in this Clinic. Twenty-nine of these cases were treated by the Whitman method, which proved to be efficacious, and which afforded results more favorable than the majority of those reported in medical literature.

The forty-five cases in our series ranged in type from the early case, in which the slipping was practically negligible, to the case of long standing, in which arthritic changes had developed. The left hip was involved in twenty-three cases, and the right in eighteen cases. In two cases the involvement was bilateral, and in two cases no notes were recorded. Eighty per cent. of the patients were males. The ages of the male patients, exclusive of two adult cases, ranged from seven to eighteen years, and the ages of the females ranged from twelve to sixteen years.

Obesity and endocrine disturbance were observed in at least nineteen of our forty-five patients, and it is possible that these factors were present in other cases in which the patients were examined before the general interest in the relation of such disturbances was stimulated. (It will be noted that our series extends over a period of twenty-two years.)

Twenty-one of our patients reported having suffered an injury; some of them had hit the hip directly, others had merely twisted the leg.

The treatment of a slipped epiphysis varies with the stage of the lesion. In the mild case, of which there were two in our series, the leg is protected by means of a flannel bandage or a leather spica. One child, after wearing the flannel spica for two months, had no further trouble, but the other child after one and one-half years had a definitely slipped epiphysis. (See Case 13 in Table I.)

Early cases of slight or moderate displacement and recent cases of severe displacement due to trauma are treated by the Whitman method of reduction. The technique of this method is well known through the writings of Dr. Whitman. Accurate determination of the reduction has recently been made possible through the introduction of a curved cassette by which vertical views of the femoral neck may be obtained (Leonard and George). Following reduction, the hip is fixed in full abduction, hyperextension, and moderate internal rotation by means of a plaster bandage. This spica must be worn until firm union has taken place; in the writer's opinion, a period of six months is required for the structures to consolidate.

Weight-bearing, in so far as it can be obtained with the leg in the abducted position, is allowed during the period of immobilization. Following the removal of the plaster spica, a flannel bandage is worn for three months, and physiotherapy and exercise are instituted to restore the muscle power. (See Figure 1.)

Advanced cases in which ossification between the displaced epiphysis and the neck has taken place, and in which new bone has formed to a great extent, call for open reduction. Operative treatment is also indicated in

Fig. 1

Roentgenogram showing an early case of slipping of the epiphysis in which the slipping amounted to one-quarter of an inch. (Case 10.)

cases in which the femoral head has flowed around the neck, so that the hook on its end is beyond 30 to 40 degrees (Fig. 2).

In long standing cases of solid union with coxa vara, in which even approximate restoration of the joint surfaces is impossible, deformity may be corrected by a wedge osteotomy. By this means, the function may be improved and the disability lessened. The more extensive the structural changes, the less correction can be obtained, but the anatomical alignment will be bettered, with a corresponding improvement in function. In our series two transtrochanteric osteotomies were performed and marked improvement of function was obtained.

Finally, there is the long standing case in which no treatment has been received or in which treatment has been inefficient. In these cases, under the influence of weight-bearing, the slipping has progressed until complete separation has occurred, or until repair has taken place with the hip in flexion-adduction deformity. The shortening may be extensive, and the function permanently impaired. Arthritic changes may be present as the result of the interference with function. A chronic back strain

FIG. 2

Roentgenogram showing complete separation of the epiphysis with a hook on the femoral head of 90 degrees in a glandular type of boy. (Case 15.)

TABLE I

CASES TREATED BY WHITMAN METHOD

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factors				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
1	M. A.	M	12 years	Left	Direct fall on hip.				5 weeks.	Slipping of ¾ of an inch.	10 years, 3 months.	No limp. Practically no shortening. No symptoms. Internal rotation normal. Slight limitation of external rotation. X-ray shows flattening of femoral head.	Good.
2	W. B.	M	14 years	Right		Yes	Yes	Yes	6 to 7 weeks.	Nearly complete separation of femoral head.	11 years, 6 months.	Slight limp. Shortening of ½ an inch. Small projection of bone restricts motion, making it impossible for the patient to cross legs.	Fair functional result. Damage to joint.
3	R. B.	M	Unknown	Right				Yes	Unknown.	Head slipped half-way off neck.		Unable to trace patient.	Unable to trace patient.
4	D. C.	M	14 years	Left and right		Yes	Yes		1 month.	Slipping of ⅛ of an inch.	1 year.	Left hip has flexion of 10 degrees, splendid rotation. The patient hunches the leg a little in walking. The right hip has flexion to a right angle, normal external rotation, and abduction ⅔ of normal. There is no internal rotation.	Good.
5	J. D.	M	16 years	Unknown				Yes	9 months.	No record.		Unable to trace patient.	Unable to trace patient.
6	R. G.	M	14 years	Right	Fall, striking hip on		Yes		1 year.	Slipping of	1 year	Patient walks without a	Excellent.

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factors				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
7	K. G.	M	9 years	Left	Fall, 10 days before coming to Clinic.	Yes	Yes		6 months.	Slipping of ½ an inch.	7 years.	No limp. Flexion to 90 degrees; external rotation, 40 degrees; internal rotation, 30 degrees. The right hip also shows involvement, which limits the result.	Excellent.
8	P. H.	F	12 years	Right	Fall on stairs.		Yes		6 months.	Slipping of ⅛ of an inch.	1 year, 3 months.	No limp. No symptoms. Normal range of motion.	Excellent.
9	J. K.	F	15 years	Left	Fall on stairs.		Yes		7 months.	Positive slipping.		Unable to trace patient.	Unable to trace patient.
10	H. L.	F	14 years	Right	Fall.			Yes	1 month.	Slipping of ¼ of an inch.	2 years, 3 months.	Normal gait. Motion to within 10 degrees of a right angle. Abduction limited by 7 degrees. Shortening of ¼ of an inch. External rotation, 25 degrees. Internal rotation, 30 degrees.	Good.
11	F. W.	F	12 years	Left	Fall, but symptoms previously.		Yes		3 months.	Complete separation of epiphysis.	3 years.	Normal internal and external rotation. Nearly normal abduction.	Excellent.
12	R. M.	M	16 years	Right		Yes	Yes	Yes	4 years.	Slipping of ¾ of an inch.	11 years, 4 months.	Very satisfactory. No trouble except a moderate limitation of motion.	Good.
13	M. R.	M	14 years	Right		Yes	Yes	Yes	1½ years.	Slipping of ¼ of an inch.	5½ years.	No eversion of thigh. Slight tendency to eversion when hip flexed. Normal flexion, abduction, and external rotation. No internal rotation.	Good.

TABLE I (*Continued*)

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factors				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
14	R. S.	F	14 years	Right		Yes		Yes	1 year.	Femoral head ¾ of *the way off* neck.	14 years.	Flexion normal. External rotation, 40 degrees; abduction to *within 10* degrees of normal. Actual loss of motion is only 10 degrees as compared with that of other hip. Shortening of ¾ of an inch. No internal rotation.	Good.
15	P. W.	M	13 years	Left		Yes	Yes	Yes	6 months.	Complete separation of epiphysis with a 90-degree hook of femoral head.	6 years.	Only a few degrees of abduction, flexion, and rotation. Considerable absorption of femoral head. (See explanation in text.)	Poor.
16	F. H.	M	14 years	Left		Yes	Yes	Yes	1 month.	No positive slipping, but slight irregularity and tendency to absorption of epiphyseal line.	4 years.	Absolutely normal motions. Shortening of ¼ of an inch.	Excellent.
17	L. P.	M	15 years	Right	Thrown from bicycle. Some pain 10 days later. Hip acute 6 months later.		Yes		6 months.	Complete separation of epiphysis.	8 years.	Walks without limp or abnormal gait. Flexion to 90 degrees, without limitation or pain. Hyperextension normal. Other motions good. Patient does everything except play football.	Good.
18	E. C.	M	7 years	Left				Yes	1 year.	Slipping of ⅛ of an		Unable to trace patient.	Unable to

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factors				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
19	R. C.	M	16 years	Left and right	Fall, but patient had limped for 9 months previously.				10 months.	Separation of left epiphysis of ¼ of an inch. Slipping of right of ⅛ of an inch.	9 years.	No trouble except for moderate limitation of motion.	Good.
20	C. C.	M	16 years	Right	Fall.	Yes			No record.	Slipping of ¼ of an inch.	12 years, 5 months.	Hip is fine, except for a touch of arthritis.	Excellent.
21	W. F.	M	16 years	Left	Fall, but had had symptoms previously.				3 months.	Femoral head slipped half-way off neck.	12 years.	No limp. No trouble.	Excellent.
22	D. DeK.	M	13 years	Left	Fall from bicycle.	Yes		Yes	6 months.	Slipping of ½ an inch. Evidence of external rotation of femur. Irritative roughening of neck.	1½ years.	Flexion, 100 degrees; abduction, 35 degrees; rotations ¾ of normal. Final position shows deformity ¾ corrected, with ¼ inch of slipping still present.	Good.
23	R. N.	M	16 years	Right			Yes	Yes	6 to 8 weeks.	Slipping of ¼ of an inch.	3 years.	Normal flexion and rotations. Abduction ½ of normal.	Good.
24	J. H.	M	16 years	Left	Fall, but had had symptoms previously.				1 week.	Femoral head halfway off neck.	1½ years.	Hip practically unkylosed in good position. Shortening of ½ an inch. Motion difficult. Arthritic changes in joint. Peculiar mottling of bone suggestive of an infectious process.	Poor.

(Continued)

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factors				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
25	E. G.	F	13 years	Right	Fall, but had had symptoms previously.				1 year.	Coxa vara with flattening of head. Irritative changes at epiphyseal line. Thinning of joint cartilage.	3 years.	Hip stiff in good position. Slight degree of motion.	Poor.
26	F. E.	M	14 years	Right	Question of injury.				4 months.	Slipping of ¼ of an inch.	2 years.	Flexion to 85 degrees. Rotations ⅓ normal. Shortening, ¾ of an inch. Patient walks with hardly perceptible limp.	Good.
27	W. E.	M	14 years	Right	Fall.				2 months.	No record.	2 years.	Patient walks with limp. Limited flexion and extension. Abduction and adduction fair. Slight rotation. More or less fixation of joint.	Poor.
28	W. L.	M	15 years	Right				Yes	6 months.	Femoral head slipped half-way off neck.	12 years.	Patient had had excellent motion for years. Twelve years after reduction, there was a coxa vara and marked callus formation. A transtrochanteric osteotomy was performed.	Good.
29	M. S.	M	16 years	Left				Yes	2 years.	Femoral head slipped half-way off neck.	4 years, 6 months.	Flexion limited by 10 degrees. Internal rotation, 15 degrees; external rotation, 45 degrees; abduction, 15 degrees. Shortening of ¼ of an inch. One year after treatment the pa-	Good.

No. of Case	Name	Sex	Age	Hip Involved	Etiological Factor				Duration of Symptoms	Preoperative X-Ray Findings	Interval between Treatment and Examination	End Results	Classification of End Results
					Trauma	Obesity	Endocrine Dysfunction	Gradual Onset					
30	F. L.	M	14 years	Right				Yes	4 years.	Femoral head slipped nearly off neck.		Patient died.	Deceased.
31	C. M.	M	17 years	Left		Yes	Yes		1 year.	Epiphysis completely displaced.		Unable to trace patient.	Unable to trace patient.
32	J. E.	M	12 years	Left					4 years.	Femoral head slipped half-way off neck.		Unable to trace patient.	Unable to trace patient.
33	F. T.	M	11 years	Left	Fall.		Yes		5 years.	No record.	15 years.	Hip ankylosed in 20 to 25 degrees of adduction. No flexion deformity. Several inches of shortening.	Poor.
34	F. MacN.	M	13 years	Left	Fall.				7 months.	Slipping of ¼ of an inch.	13 years, 7 months.	Normal hip. Motion not restricted.	Excellent.
35	R. B.	M	16 years	Left	Injured in football game.	Yes	Yes		2½ years.	No record.	2 years.	Bony ankylosis between head and acetabulum. Patient stands with definite left lumbar curve. No rotations.	Poor.
36	R. M.	M	16 years	Left		Yes	Yes		2 years.	Femoral head turned half-way around and united with neck posteriorly.	2 years.	Hip stiff in good position. (Prognosis recognized as poor from beginning of treatment.)	Poor.
37	N. Z.	F	16 years	Left	Fall.				3–4 years.	No record.	20 years.	No difficulty since operation. Walks without a limp. Abduction limited ½. Internal rotation ½ of normal. Normal external rotation and flexion. Slight tendency to eversion.	Good.

FIG. 3

Case 23. R. N. Roentgenogram showing slight slipping of the epiphysis. Symptoms of two months' duration.

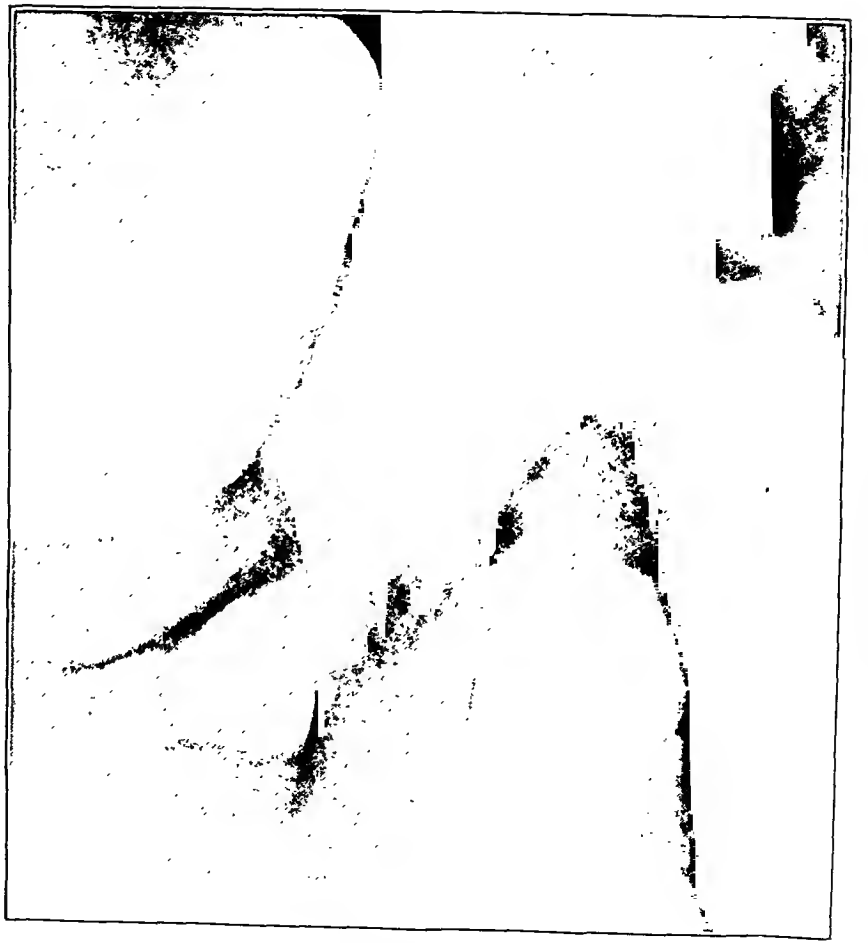

FIG. 4

Case 23. R. N. Roentgenogram taken three and one-half years after manipulative reduction.

or mild curvature may have developed. Occasionally a complete ankylosis of the hip joint is seen.

The treatment of these long standing cases depends upon the pathology. Occasionally a reconstruction operation, an arthrodesis, or an arthroplasty is indicated. The adult patient with secondary arthritis presents a particular problem from a therapeutic standpoint, as conservative measures afford only temporary relief and such patients are usually poor operative risks.

Four cases of this advanced type have come to our attention. One patient (Case 35, Table II) had been improperly treated for two and a half years before he came to our Clinic, owing to the fact that the lesion had not been recognized. An attempt to reduce the displacement by operation proved ineffective, and two years later a modified arthroplasty was done. The result was good. The second patient, thirty-seven years of age, had suffered severe pain in the hip for over two years. On examination, both internal and external rotation, abduction, and flexion were found to be limited. A diagnosis of an old slipped epiphysis was made, and a reconstruction operation advised, but the patient refused the treatment. In the third and fourth cases, epiphyseal injuries had been suffered many years before examination, and conservative measures were used to compensate for the shortening.

END RESULTS

Reference has already been made to the outcome in the following cases: two mild cases treated by flannel bandages; two cases of coxa vara treated by transtrochanteric osteotomy; one advanced case in which a modified arthroplasty was performed; three advanced cases treated by palliative measures.

Every effort was made to examine the twenty-nine patients treated by the Whitman method and the eight patients treated by open reduction. Twenty-five of the former group were located. In these cases the time interval between treatment and the reexamination varied from one to fourteen years; twelve to fifteen years had elapsed in six cases, six to eleven years in five cases, and one to six years in fourteen cases.

In the classification of the clinical end results, the following standard was used:

Excellent: Restoration of practically normal motion. Less than one-quarter of an inch of shortening. No symptoms.

Good: Slight to moderate limitation of motion. Slight shortening. No symptoms. Function sufficient for ordinary purposes.

Fair: Motion satisfactory for the routine functions, but definitely restricted in some respect.

Poor: Hip definitely restricted in motion. Movement difficult.

In twenty, or 80 per cent., of the twenty-five cases, excellent or good results were secured; in two, or 8 per cent., fair functional results were obtained; and in three, or 12 per cent., the outcome was poor. Complete

details of the amount of motion are given in Table I. Figures 3, 4, 5, and 6 are illustrative of the reduction obtained in cases of varying degrees of slipping.

In the group in which open reduction was done, five of the eight patients were located. Two to twenty years had elapsed since treatment. In these cases, one excellent result, one good result, and three poor results were obtained. In one of the three cases in which the outcome was poor, the prognosis was poor from the beginning of treatment; in another case, the lesion had been of five years' duration when treatment was instituted; and, in the third case, improper treatment had been carried out for several years before the patient came to our Clinic.

It is the writer's opinion that, provided the patient is treated by the Whitman method within a reasonable length of time after the onset of the condition, good to perfect function may be restored. In cases of slight to moderate displacement, the best results may be expected when treatment is instituted within a month's time; and, in cases of severe trauma, the outcome is most satisfactory when reduction is made within forty-eight hours. After a displacement has existed for six months or more, the mass of bone involving the epiphysis, neck, and joint may be so great that reduction is difficult, if not impossible. In cases of severe trauma the reaction that sets in is more intense; consequently, unless early treatment is instituted, operative reduction must be considered.

When manipulation fails as the method of treatment, one of two factors is responsible: either the displacement was not reduced sufficiently early, or the limb was not immobilized for a sufficiently long period. In some cases active treatment will be required for more than a year. Case 22 (Table I) illustrates well this need of extended treatment.

The patient was an extremely obese boy, weighting 179 pounds at thirteen years of age. Following manipulation, the limb was immobilized in a plaster spica for five months, and then a leather spica was worn for four months. At the end of this time, the roentgenogram showed that the slipping had progressed. Reduction by the traction method was then attempted: a pin was driven through the tibia, the limb was manipulated slightly, and traction of twenty pounds was applied. The traction was continued for four months; at the end of this time there was definite bone repair. No weight-bearing was allowed for another five months. A good result was obtained in this case. (See Figures 7-A, 7-B, 7-C, and 7-D.)

The use of traction seems to hold a great deal of promise. It has the decided advantage of shortening the period of immobilization.

In the advanced case, in which operative reduction is indicated, the prognosis depends upon the extent of the pathology. In Case 34 (Table II), in which the displacement was only slight and in which treatment was instituted seven months after the onset of symptoms, a perfectly normal hip resulted from operative interference. On the other hand, in Case 36 (Table II), a glandular type of boy who had had symptoms for two years before he was treated, a stiff hip was the result of operative treatment (Fig. 8). In this case the prognosis had been recognized as poor from the beginning of treatment, as the femoral head was turned half-way around

FIG. 5

Case 11. F. W. Roentgenogram showing complete separation of the femoral head. Symptoms of three months' duration.

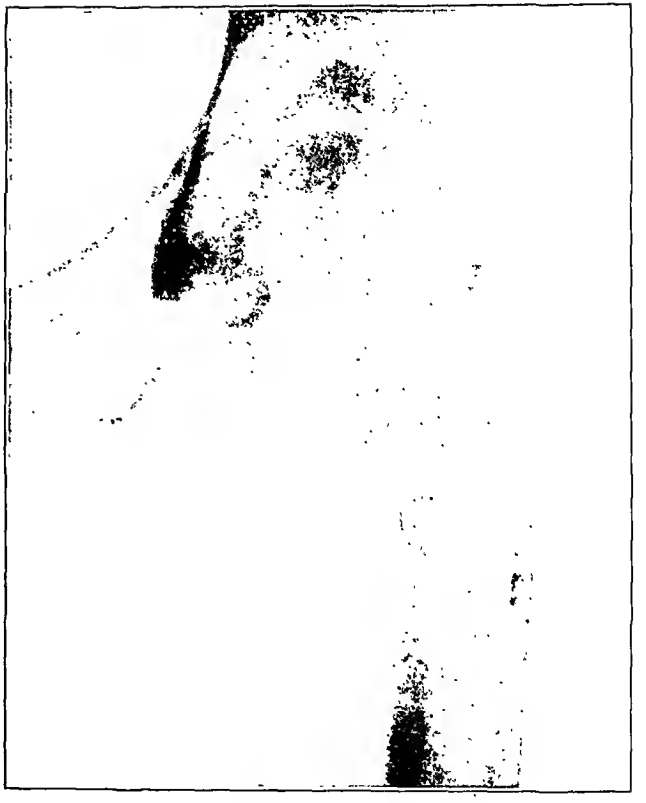

FIG. 6

Case 11. F. W. Roentgenogram taken three and one-half years after manipulative reduction.

Fig. 7-A

Fig. 7-B

Case 22. D. DeK. A series of roentgenograms taken throughout the course of treatment.

Fig. 7-A. The original displacement.

Fig. 7-B. Extreme slipping and shortening of the femoral neck following manipulation and retention for five months in a plaster spica.

Fig. 7-C

Evidence of repair four months after the institution of traction.

Fig. 7-D

Ten months after the institution of traction. Firm union, but no change in the relation of head and neck.

FIG. 8

Case 36. R. M., operated upon two years after the onset. A poor result was obtained in this case.

and united posteriorly with the neck. In Case 15 (Table I) a better result would probably have been obtained if an operative reduction had been carried out, since the femoral head showed a hook of 90 degrees (Fig. 2).

CONCLUSIONS

Closed manipulative reduction has proved efficacious in a series of twenty-nine cases. In 80 per cent. of these cases, excellent or good functional results were obtained; in 8 per cent., the functional results were fair.

Successful treatment by closed reduction depends upon:

1. Early institution of treatment.
2. Accomplishment of complete reduction.
3. Active treatment for a sufficiently long period.

The new curved cassette makes it possible to ascertain whether or not reduction has been accomplished.

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OPERATIVE TREATMENT OF HOLLOW FOOT

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Of the older methods of operative treatment of hollow foot, the author has found that of Dr. Scherb[1] the most useful, but experience has demonstrated certain handicaps in this technique. In this method, the oblique position of the metatarsal bones is corrected by an osteotomy near their bases, and the new position is maintained by a transosseous attachment of the extensor hallucis longus tendon or of the tendons of the other long extensors of the toes. This has disadvantages, for, with the loss of the long extensor tendon, the toe assumes the position of hammer toe through the action of the flexor. This position results in inflammatory processes on the end of the toe, the treatment of which is difficult. In addition to this, the pull of the transplanted extensor tendon

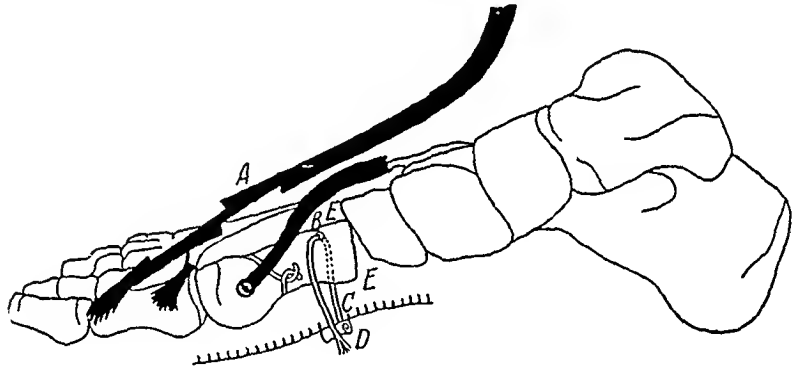

FIG. 1

A, the lengthened extensor hallucis longus tendon; *B*, the transplanted extensor hallucis brevis tendon; *C*, suture; *D*, attachment of the distal fragment to the skin; *E-E*, osteotomy. (*Courtesy of Johann Ambrosius Barth, Leipzig, Germany.*)

is not sufficient to maintain the corrected position of the metatarsal bone, for the reason that all of the soft tissues of the sole are shortened, which tends to produce a recurrence of the deformity, and experience shows that, after osteotomy and the placing of the metatarsal bone in its new position, in the majority of cases the deformity returns. Also, the transversoplanus of the forefoot, which resembles somewhat the pronation of the metatarsal bone, plays an important rôle in the deformity.

The method to be described eliminates the disadvantages of the method of Scherb and conserves only the principle of the osteotomy of the metatarsal bone. In the author's opinion, this is the only physiological way to correct the deformity without derangement of the relation of or injury to the bones. It is necessary to correct: (1) the oblique position

of the metatarsal bones, with flattening of the arch of the foot; (2) the impediment of the spread foot; (3) the supination of the metatarsal bones; and (4) the contracted extensor hallucis longus tendon or other long extensor tendons.

The method described at one time by the author's assistant, Dr. Rosenzweig[2], consists of the plastic lengthening of the extensor hallucis longus tendon, the dissection of the extensor hallucis brevis tendon from its insertion on the first phalanx, and the drilling of a straight frontal canal near the head of the metatarsal bone, through which the extensor

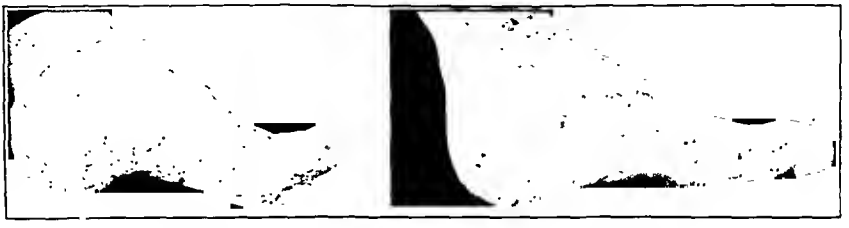

FIG. 2-A
Before operation.

FIG. 2-B
Four years after operation.

hallucis brevis tendon is pulled and sutured on the inner border of the toe. The purpose of this manipulation is to preserve the spread of the metatarsal arch and to hold in supination the pronated metatarsal bone. An osteotomy of the metatarsal bone near its base is then performed in an oblique direction, in order to make the distal fragment slide downward in the direction of the sole and thus lower the high arch. In order to make secure the new position and to overcome the pull of the shortened soft tissues of the plantar arch, which tend to distort the distal fragment upward into its old position, parallel canals are driven from the dorsal surface of the distal fragment to the plantar surface. Through these canals, silk, catgut, or kangaroo ligatures are carried, the upper ends of which are fastened to the periosteum or to other soft parts over the surface of the bone. By means of these sutures, the distal part of the metatarsal bone is then pulled into position and secured to the skin temporarily by a pad

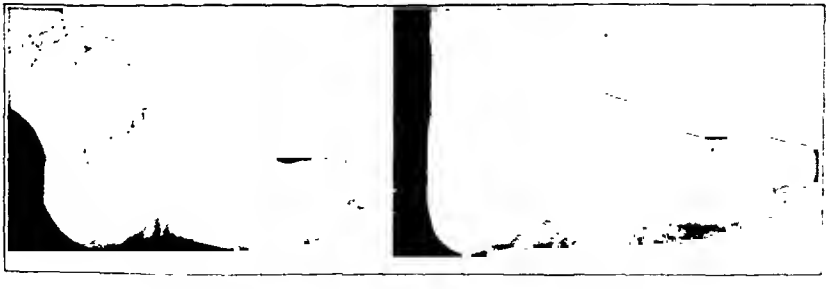

FIG. 3-A
Before operation.

FIG. 3-B
Three years after operation.

of gauze. Finally, the cut portions of the tendon of the extensor hallucis longus are sutured. The operation is completed by the redressement of the hammer-toe position of the toes, or, if necessary, the same operation is performed on the other metatarsal bones. The foot is immobilized in plaster for six weeks. At the end of three weeks, the patient is allowed to walk by means of an iron secured to the plaster.

This operation has been performed by the author in twenty-two cases during the past three years, and the results have been good.

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CARTILAGINOUS INCLUSIONS IN RACHITIC BONES AND THEIR POSSIBLE RELATIONSHIP TO CARTILAGINOUS TUMORS*

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Having observed and studied separate islands of cartilage in spongiosa of bones removed at autopsy from a case of healed rickets, clinical and experimental investigations have been made to determine how frequently this finding is noted. Clinical material for studying rickets is scarce, as the disease is not fatal and it is rarely necessary to remove rachitic bones at operation. Hence this study is made from the material obtained in the above mentioned case and in cases of experimentally produced rickets and from roentgenograms of clinical cases.

The occurrence of islands of cartilage in the bone following rickets was noted by Virchow[1]. Pappenheimer[2], as well as others, has reported the presence of these "inclusions" in experimental rickets. During the active stage of rickets, Shipley[3] states that islands of cartilage are found in the metaphysis. He calls these pseudo-enchondromata.

Since no mention of the occurrence of cartilaginous inclusions in the epiphyses following rickets could be found in the literature, either in reports of clinical cases or experimental work, the following case is reported in some detail.

CASE REPORT

A white female child, five years of age, with a past history of rickets and physical findings of a pigeon breast, Harrison's groove, and a rachitic rosary died as a result of tuberculous meningitis. This was proved at autopsy. Several long bones and portions of ribs and vertebrae were removed for study. Roentgenograms of the long bones (Fig. 1) show the rachitic process to be healed and only slight evidence of cartilaginous inclusions. Photographs of longitudinal sections of these bones reveal numerous separate islands of cartilage, especially in the epiphyses (Fig. 2).

Sections made for microscopic study reveal numerous "rachitic inclusions" in the spongiosa of the epiphyses of the long bones (Fig. 3), in the ribs (Fig. 4), and in vertebrae (Fig. 5). A few islands of cartilage are also noted in the metaphyses of the long bones. In each bone the rachitic process is healed. As is seen in Figures 3, 4, and 5, the islands of cartilage are small to large. Some are undergoing calcification, others appear to lie in osteoid trabeculae, while others seem to be "latent". The cells of these cartilaginous inclusions reveal different types. A majority are large with cytoplasmic changes and the nuclei show the fragmentation and irregularity commonly seen in the cells of the zone of calcification of the epiphyseal plate. In fact, calcification is occurring in a number of these cell groups. Cells of other groups, however, are smaller, the nuclei are more regular, not fragmented, and spindle, oval, and round in shape, simulating somewhat the cells in the zone of proliferation of the epiphyseal cartilage. In a few of these latter islands of cartilage there is little or no evidence of calcification. The isolated islands

* Read before the General Surgery Section of the California Medical Association, Riverside, May 3, 1934.

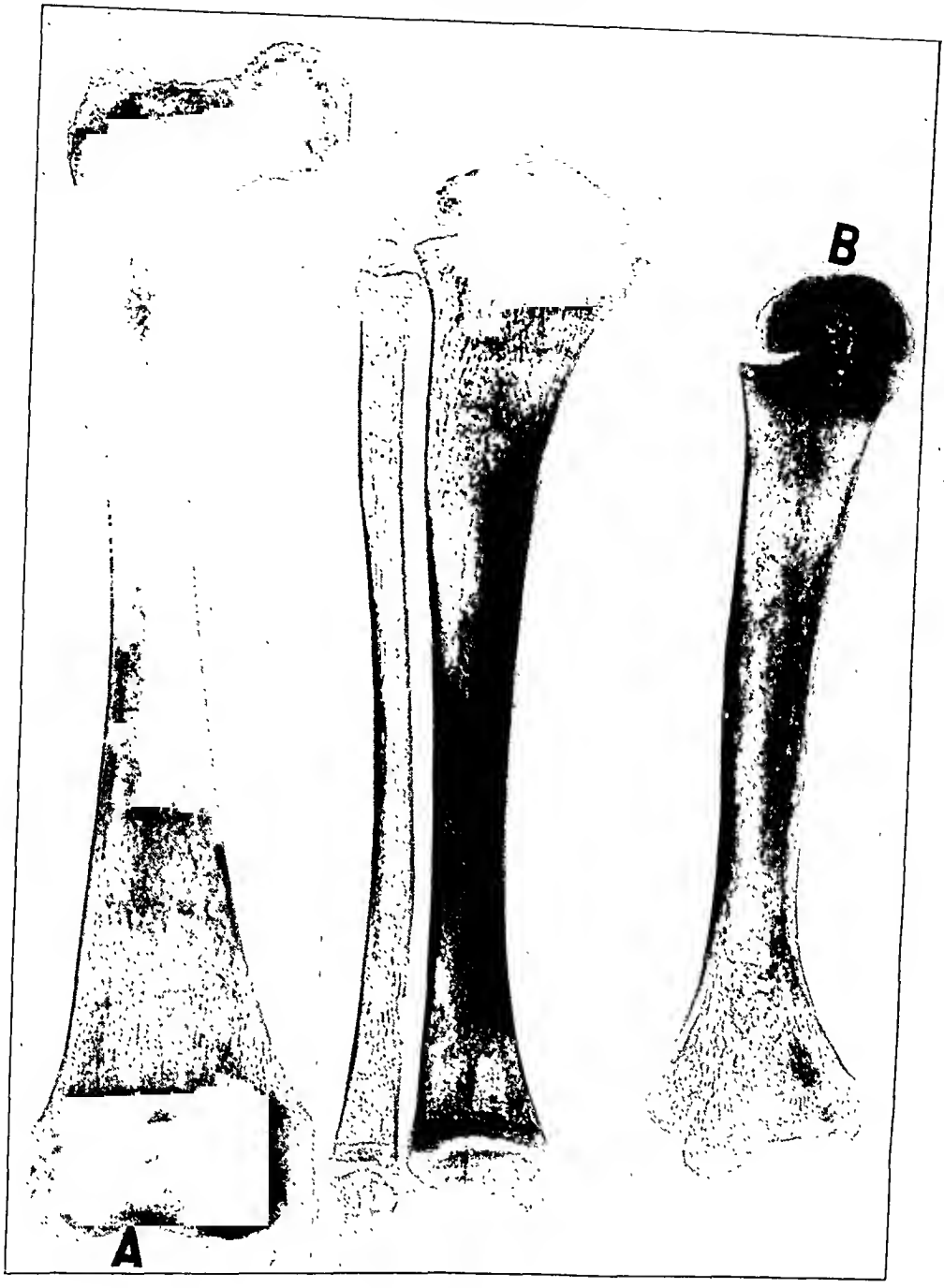

FIG. 1

Roentgenograms of femur, tibia, fibula, and humerus from a clinical case of healed rickets. Slight irregularity in density in the lower femoral epiphysis (*A*) and in the upper humeral epiphysis (*B*). Compare with Figure 2.

of cartilage cells seen in the ribs and vertebrae have a cellular structure similar to those in the long bones.

It is of especial interest that the roentgenographic studies (Fig. 1) show only slight evidence of these islands of cartilage. This is of significance clinically and proves that these rachitic inclusions may easily be overlooked.

EXPERIMENTAL WORK

To make a further study of the occurrence of cartilaginous inclusions subsequent to rickets, the following experimental work was done.

One hundred and thirty-two young white rats and five young rabbits were used. Rickets was produced in all, with the exception of twenty rats and five rabbits which were used as a control group, with the McCollum diet No. 3143 and the Steenbock diet No. 2965. Viosterol and dicalcium phosphate were used to produce healing. The rate of healing was regulated, being produced slowly in some groups and more rapidly in others.

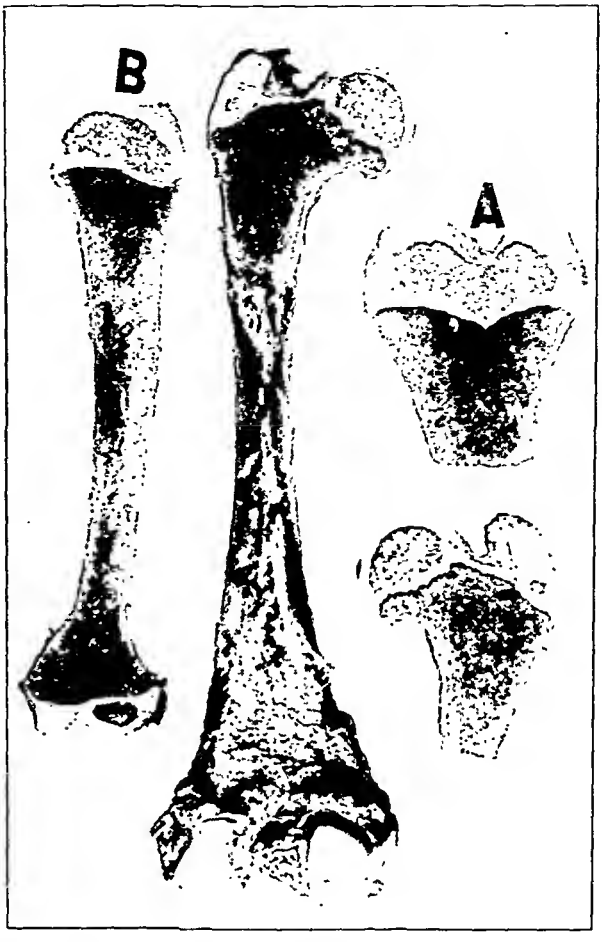

FIG. 2

Longitudinal sections of bones shown in Figure 1. White cartilaginous inclusions in spongy bone, especially in the epiphyses. The epiphyses, *A* and *B*, showed only slight irregularity in density in Figure 1.

Whether the animals were normal, actively rachitic, or healed rachitic, they were sacrificed and the following procedures carried out. The soft parts overlying the hind-leg bones were removed and in each leg the femur and tibia were amputated in the mid-shaft, thus leaving the knee joint intact. Celloidin sections for microscopic study were made longitudinally through each specimen. This exposed the epiphysis and metaphysis of both the femur and the tibia.

EXPERIMENTAL RESULTS

Twenty normal, non-rachitic, young rats and five young rabbits revealed normal epiphyseal lines; no separate cartilaginous inclusions were found.

A second group of nineteen rats with active rachitic processes was

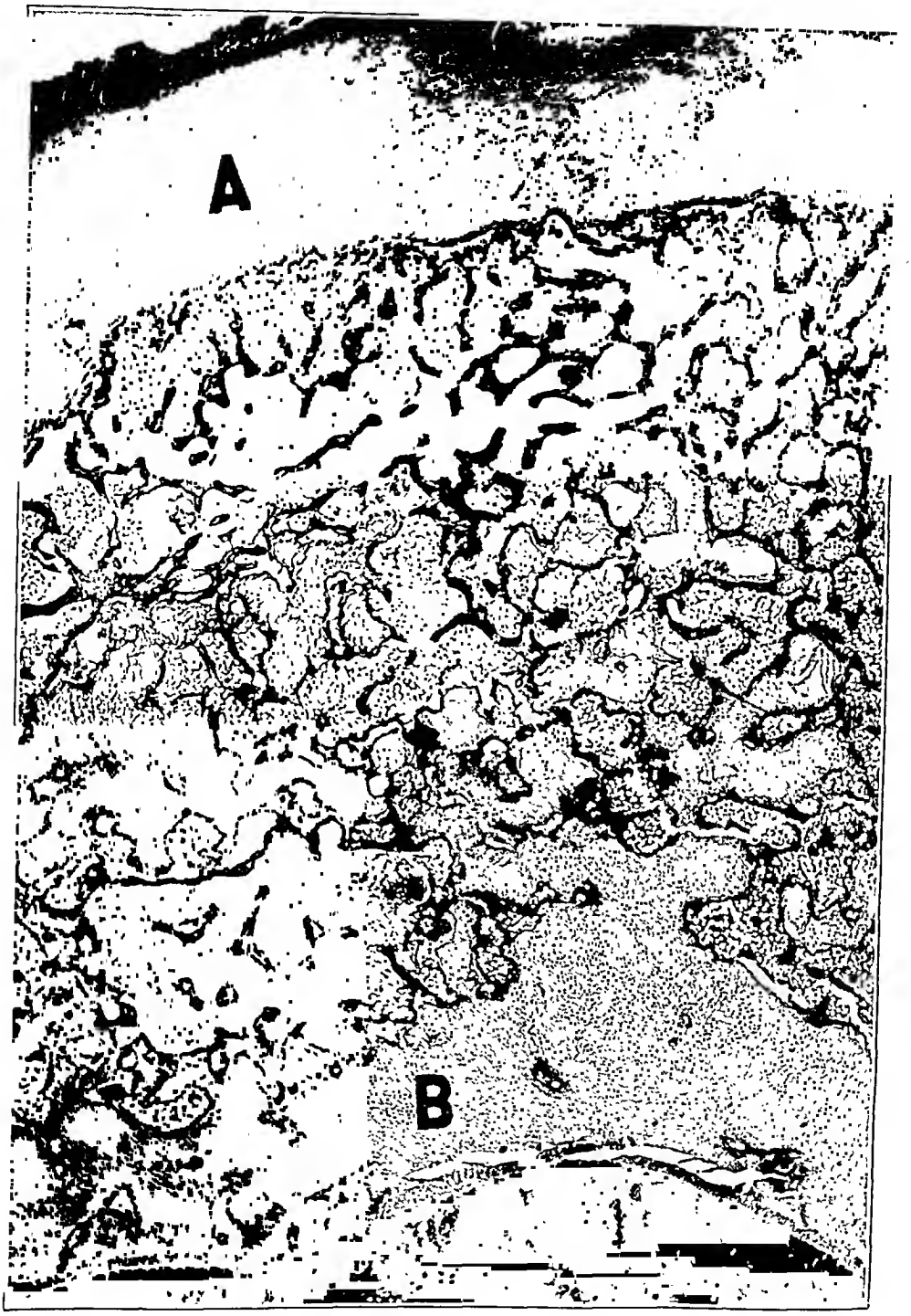

FIG. 3

"Rachitic inclusions" in humeral epiphysis. Articular cartilage, *A;* epiphyseal cartilage, *B.*

studied. No antirachitic treatment had been given these animals, and none of the animals showed healing on microscopic examination. The typical widened, irregular, and disorderly arrangement of cells in the zone of cartilage proliferation was seen. Only an occasional patch of calcification in the zone of provisional calcification was observed. Al-

FIG. 4

Richly cellular cartilaginous inclusion in rib from a clinical case of healed rickets.

though the cartilage cells extended for a considerable distance into the metaphyses in irregular tonguelike processes, very few separate islands of cartilage could be found in this region, and none in the epiphyses, or in the cortical portions.

In twenty-nine rachitic rats, healing took place rapidly (ten to fourteen days). Microscopically the rachitic process was practically healed,

FIG. 5

Inclusions of cartilage in vertebrae from a clinical case of healed rickets. Vertebral cartilage plate, *A*.

as shown by a narrowed and orderly arrangement of cells in the zone of cartilage proliferation and also by a zone of calcification. In 66 per cent. of the rats in this group, islands of cartilage separate from the epiphyseal

TABLE I

CARTILAGINOUS INCLUSIONS IN BONES AFTER RICKETS.
TWENTY-NINE RATS. HEALED RAPIDLY.

	Epiphysis	Metaphysis	Cortical Region	Total Cartilaginous Inclusions
Number of rats	4	11	4	19
Occurrence				66 per cent.

plate were noted in the metaphysis, epiphysis, or cortical region (Table I).

In another group of forty-three rachitic rats, healing took place more slowly (fifteen to twenty days). Healing was present on microscopic examination. Cartilaginous inclusions were found in 26 per cent. of the rats in this group (Table II).

TABLE II

CARTILAGINOUS INCLUSIONS IN BONES AFTER RICKETS.
FORTY-THREE RATS. MODERATELY SLOW HEALING.

	Epiphysis	Metaphysis	Cortical Region	Total Cartilaginous Inclusions
Number of rats	3	6	2	11
Occurrence				26 per cent.

In twenty-one rats with an active rachitic process, healing took place slowly (twenty-two to more than thirty days). On microscopic examination, the rachitic process was found to have healed and cartilaginous inclusions were present in 19 per cent. of the rats (Table III).

TABLE III

CARTILAGINOUS INCLUSIONS IN BONES AFTER RICKETS.
TWENTY-ONE RATS. HEALED SLOWLY.

	Epiphysis	Metaphysis	Cortical Region	Total Cartilaginous Inclusions
Number of rats	0	3	1	4
Occurrence				19 per cent.

Figures 6, 7, and 8 show inclusions of cartilage in metaphysis, epiphysis, and cortical region, following experimental rickets.

DISCUSSION

From the foregoing experiments, it is seen that the majority of inclusions in healed rickets are in the metaphysis, with a lesser number in the epiphysis and cortical region. The term "cortical region" is used in preference to "cortex", as the cortex is not well formed in the metaphyseal

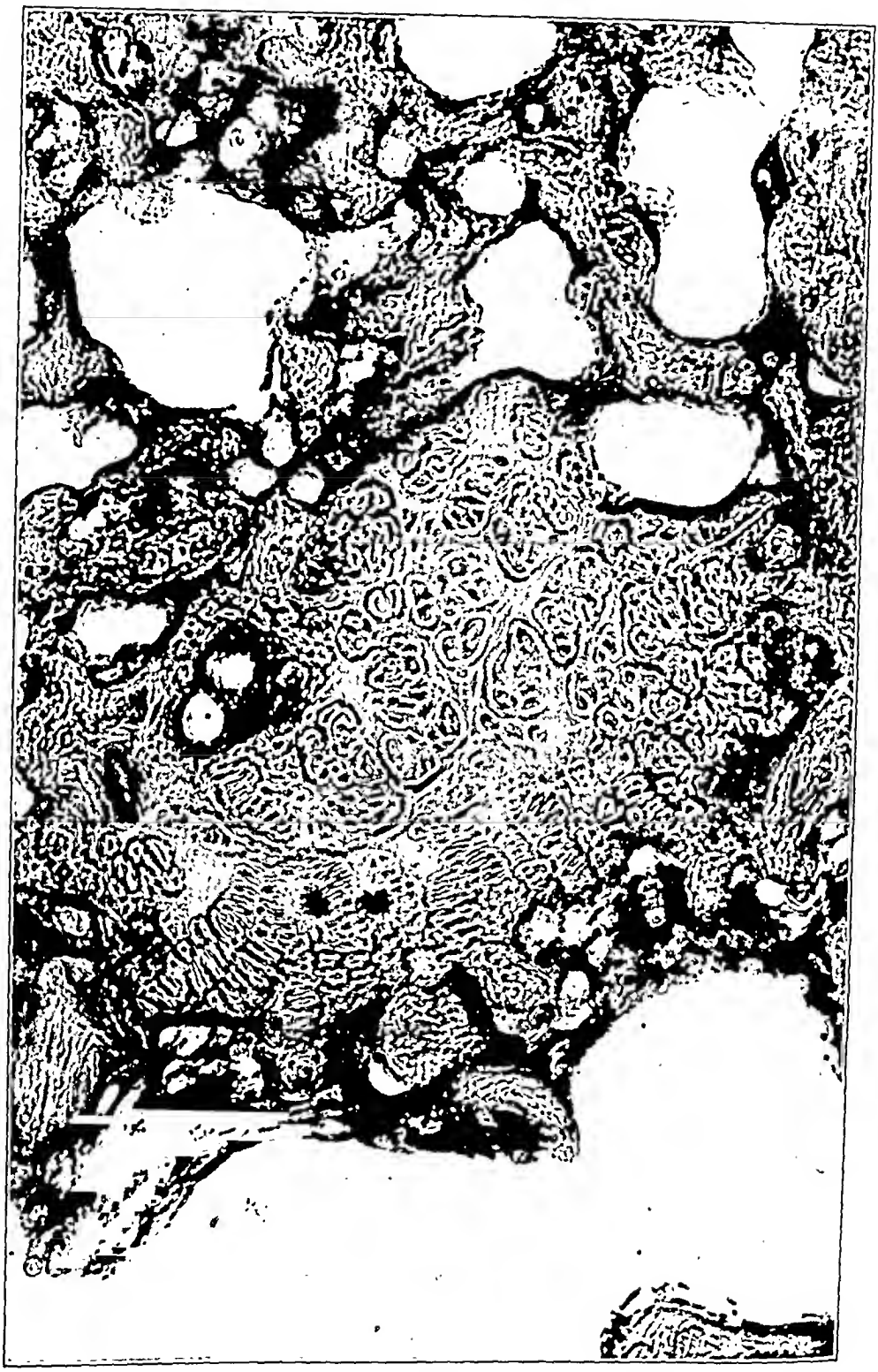

FIG. 6

Cartilaginous inclusion in lower femoral metaphysis from a healed rachitic rat.

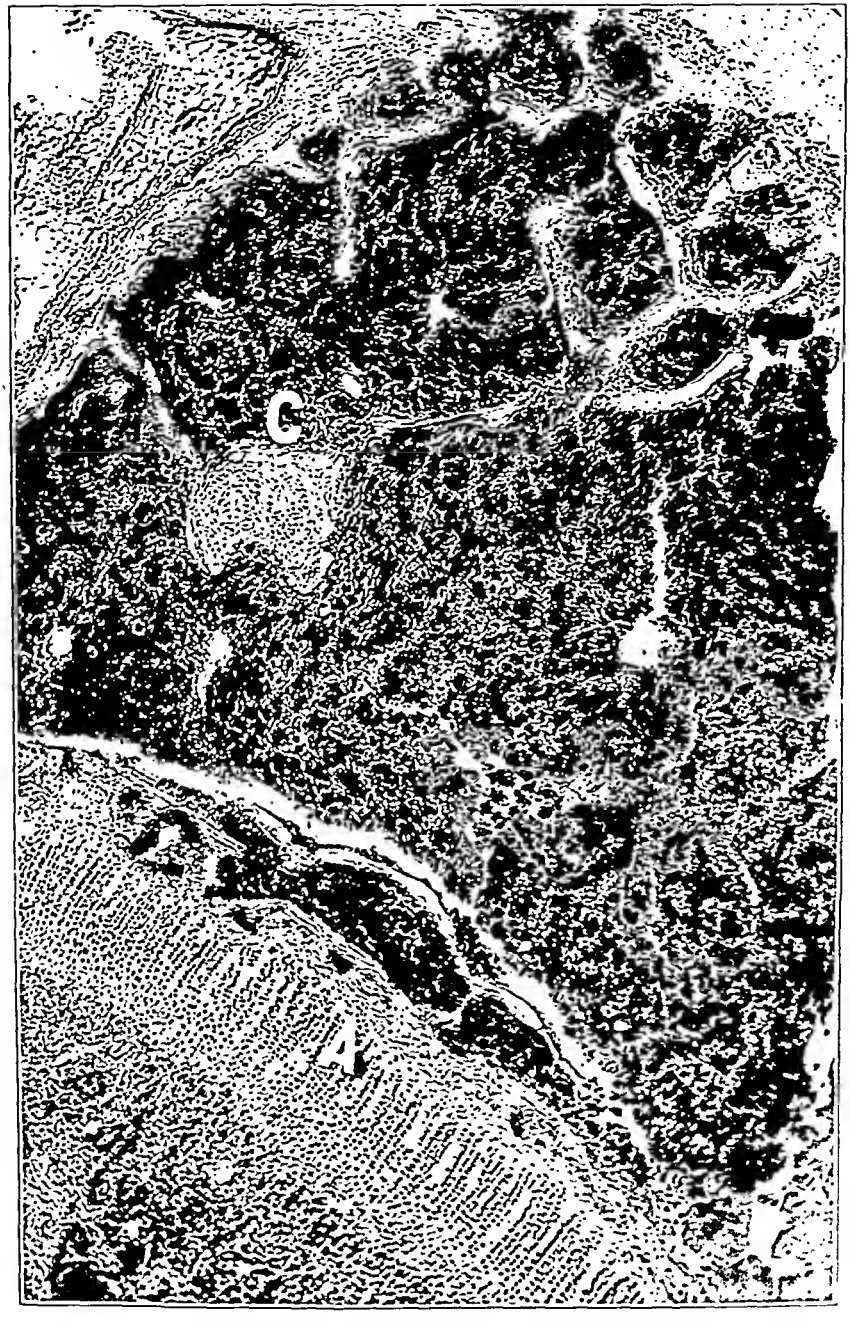

FIG. 7

Richly cellular, cartilaginous inclusion (C) in lower femoral epiphysis from a healed rachitic rat. Epiphyseal line, A.

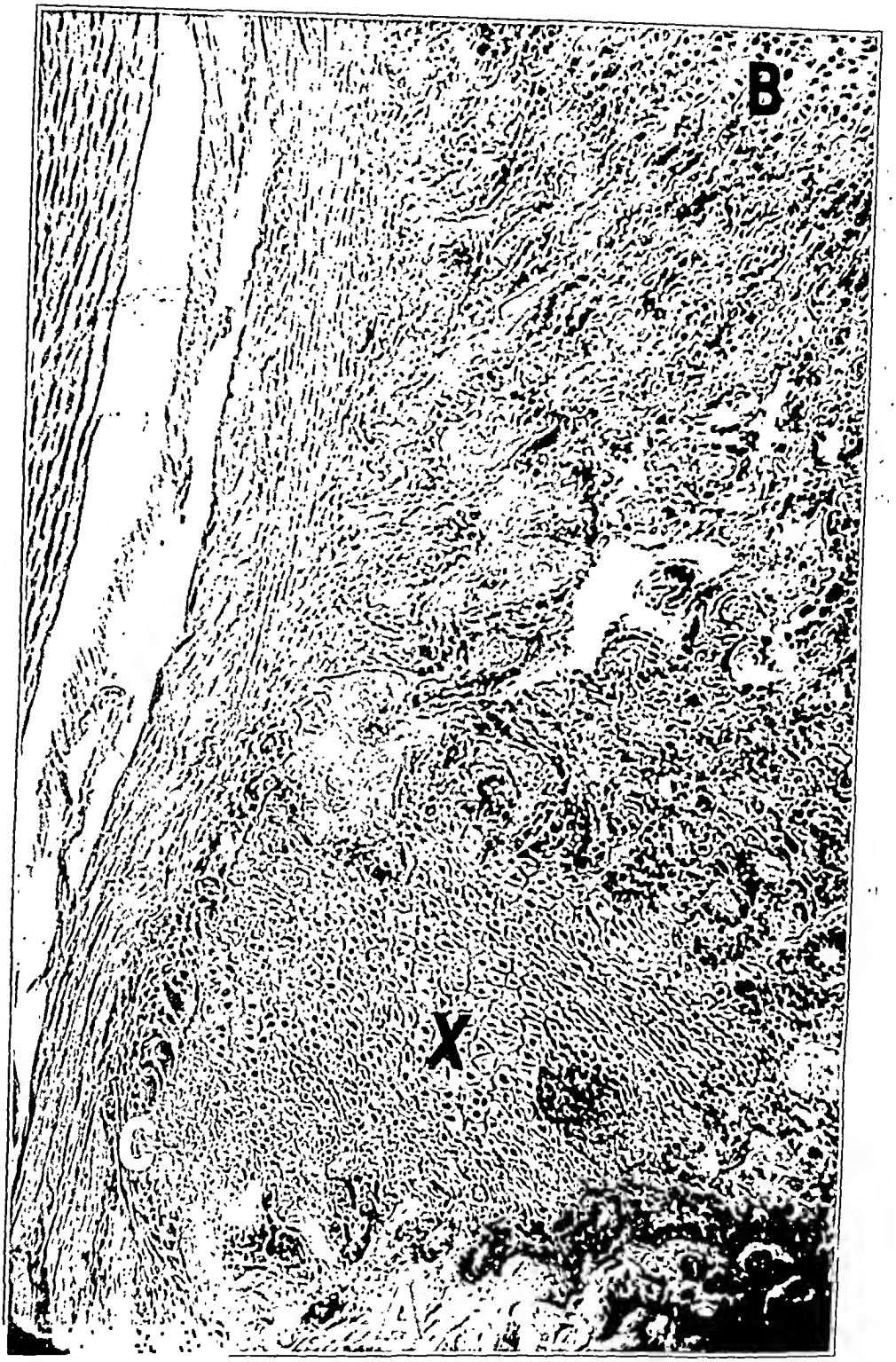

FIG. 8

Cartilaginous inclusion (*X*) in cortical region from a healed rachitic rat. Cortex, *A;* epiphyseal cartilage, *B;* periosteum, *C*, with associated giant cells.

region of a growing bone, and the experiments were not continued for a period long enough to see these inclusions actually present in the cortex. The probable reason for fewer inclusions of cartilage in the bones of the animals in which healing took place slowly is that the longer period of time used to produce healing allowed a prolonged opportunity for replacement of the islands of cartilage by calcification and ossification. The fate of these islands of cartilage presents an interesting problem. As shown in these experiments, the rachitic rats in which healing took place slowly showed the fewest number of cartilaginous inclusions. Microscopically there was evidence of calcification and osteoid tissue in variable amounts in and about a large number of the inclusions. Hence it seems logical to assume that, with a longer period of healing and a return to normal growth, calcification and replacement by osseous tissue would occur in a majority of the inclusions. Should calcification and ossification not occur in one or more of these islands, either with normal growth or as a result of some general disease, nutritional upset, or endocrine disturbance, a nest or nidus of cartilage cells would remain.

The foregoing clinical case report illustrates that these islands of cartilage will persist after rickets for a considerable period of time. At the time of her death, this patient was five years old, which is three to four years after the usual occurrence of rickets, according to Howard and Mills[4]. These authors state that only exceptionally does rickets occur after two years of age and then it is usually of the coeliac or renal type of which this child gave no evidence. In renal rickets, separate islands of cartilage are quite often noted in the spongy bone of the metaphysis[5,6].

Thus, seeing that cartilaginous inclusions in bone do result from rickets and may persist for some time after healing has occurred, the question arises: "What relation, if any, may these islands of cartilage have to the formation of cartilage tumors?" As already noted, the cells present in the inclusions vary from a large, mature type of cell, seen in the normal zone of calcification, to a small, round, oval, and spindle-shaped cell similar to those seen in the normal zone of cartilage proliferation (Figs. 4 and 7). The presence in an inclusion of this more embryonic type of cartilage cell suggests that hyperplasia could result from such cells with production of a cartilaginous lesion.

Whether hereditary deforming chondrodysplasia, which is usually associated with multiple cartilaginous exostoses, is related to rickets or not is questionable. In this interesting condition, besides the definite hereditary tendency so well pointed out by Ehrenfried[7], a congenital factor apparently exists, for the deformities and tumors may be found at birth[8, 9, 10, 11]. This would tend to eliminate rickets as an etiological agent, for, although some writers claim that congenital or foetal rickets does occur, a case of undoubted congenital rickets has not been reported so far, according to Howard and Mills[4] and Shipley[2]. The multiple exostoses and deformities, often symmetrical, suggest, however, a disturbance in normal growth and ossification, due very likely to some nutri-

tional or metabolic disturbance which in this respect might simulate rickets.

Certain ecchondromata are definitely related to rickets. Of these, the most commonly observed are the nodular outgrowths of cartilage felt at the costochondral junction during or after rickets and spoken of as a "rachitic rosary". These nodules are due to an abnormal and irregular hyperplasia of cartilage concurrent with active rickets. With healing of the rachitic process, many of these nodules disappear.

It seems quite probable that chondromata might develop from the islands of cartilage which persist in the spongy bone after rickets. Some of these islands contain a proliferating type of cell. Hyperplasia of these cells, or a reversion to a more embryonic type by the elements in such an island, could result in the formation of a chondroma. Single chondromata are located largely in the phalanges and metacarpals and, as pointed out

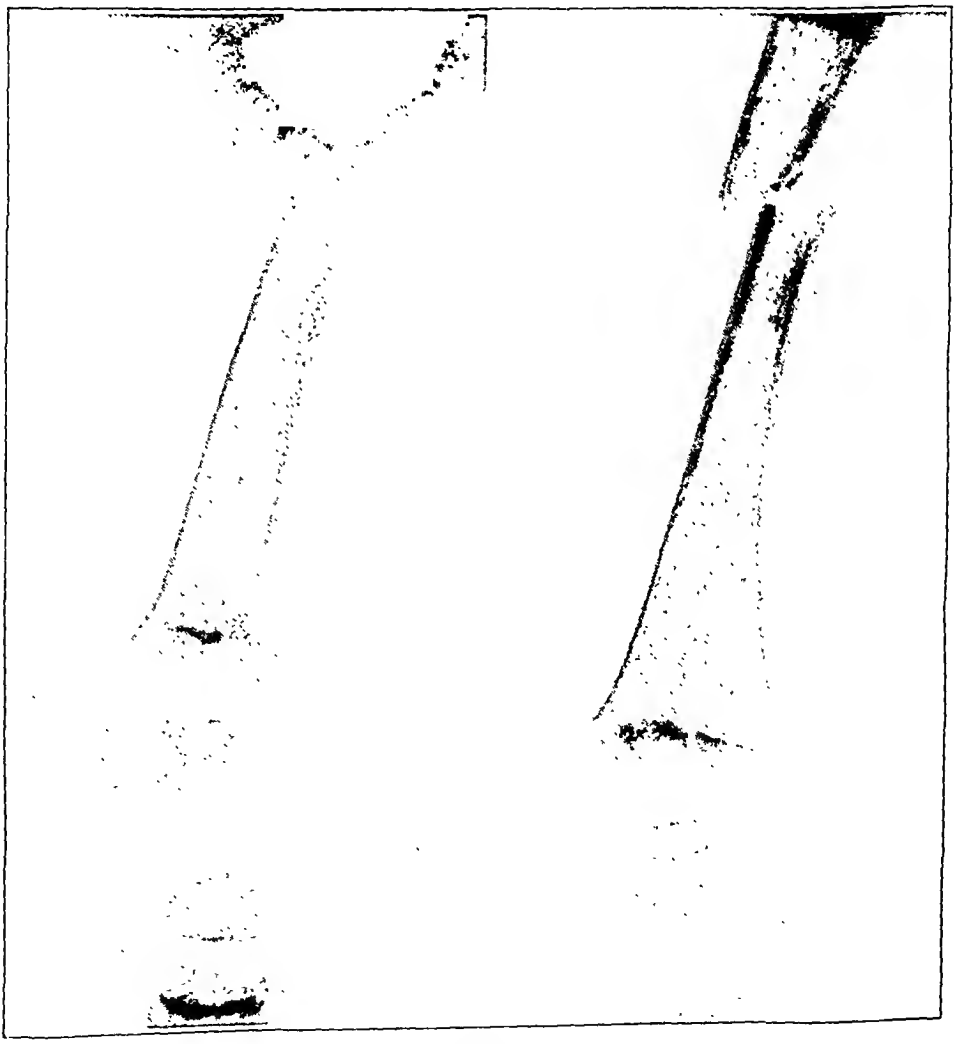

FIG. 9

Active rachitic process in both epiphyseal regions of the knee in a girl two years old. Fracture in upper third of femur.

by Phemister [12], rachitic inclusions there would be less often expected than at the ends of the long bones which grow rapidly. No record of rachitic inclusions in these small bones was found in the literature and studies of these small bones were not made in the foregoing clinical case or experiments. Benign cartilaginous tumors have been reported a number of times as occurring in long bones, ribs, and vertebrae, which are the locations where rachitic inclusions were found in the case reported here.

The persistence of a rachitic inclusion in the cortex, occurrence of which is less frequent than in the spongy bone, might serve as the nidus for the development of an exostosis. Ehrenfried [13] demonstrated the presence of clumps or nests of cartilage cells persisting uncalcified in the thickened and hyperactive periosteum and cortex of the end of the shaft in a case of hereditary deforming chondrodysplasia. These groups, he

FIG. 10

Roentgenograms of case shown in Figure 9, taken fifty-two days later. Rachitic process practically healed and abundant bony callus at fracture site. Note area of reduced density in the femoral metaphysis with semilunar ring of increased density about the medial portion. The cortex is expanded and partly absent on the lateral surface of the area, which may represent a cartilaginous inclusion.

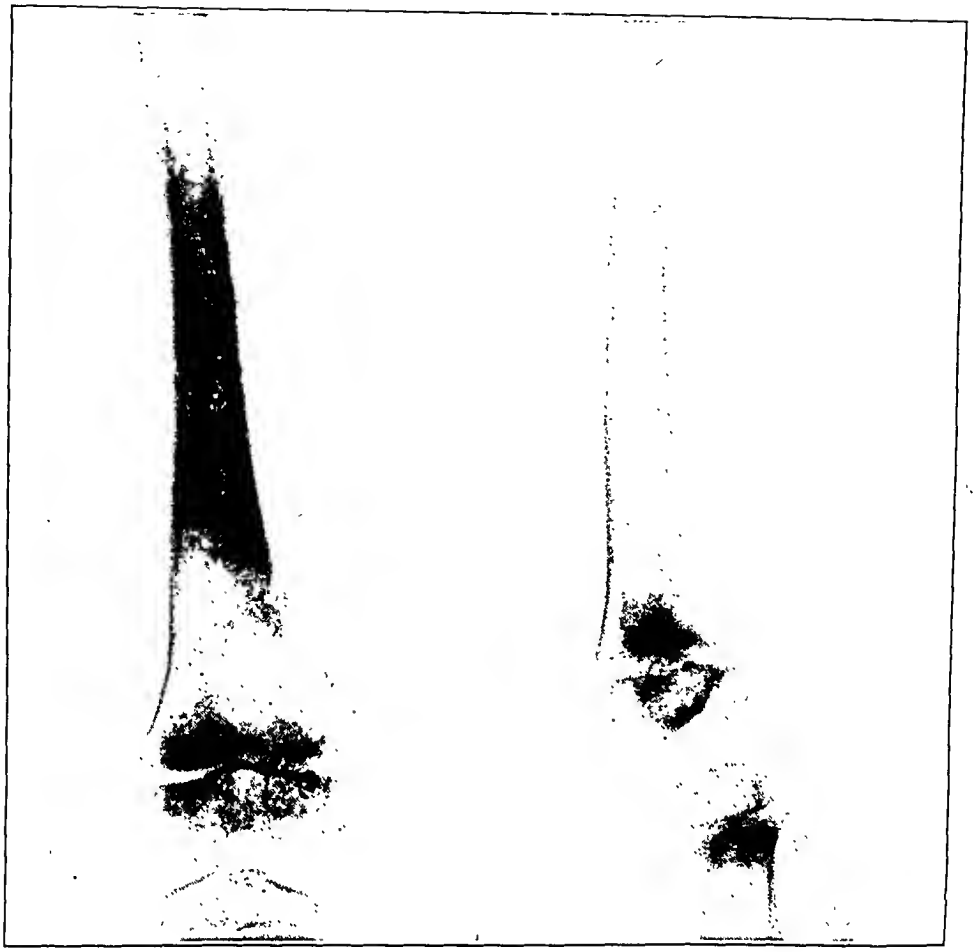

FIG. 11

Roentgenograms of case shown in Figures 9 and 10, taken two years later. No sign of the rachitic inclusion or fracture. The rachitic process has healed.

stated, may develop later into cartilaginous exostoses or chondromata. Whether such a growth would occur spontaneously or follow some stimulus, such as trauma, it is difficult to say. The following case report and study is of interest in this respect.

A Mexican female child, two years of age, entered the University of Chicago Clinics, July 10, 1931, following a fall in which she sustained a fracture of the upper third of the right femur. Physical examination revealed, in addition to the fracture, a rachitic rosary and swollen, somewhat tender epiphyses. The child was well developed, but slightly undernourished.

Figure 9 shows the fracture in the upper one-third of the femur and, at the knee, the typical widening, irregularity, and haziness of an active case of rickets.

Figure 10 shows the roentgenograms of the same case taken fifty-two days later, following active antirachitic treatment. Abundant bony callus at the fracture site is seen, and the rachitic process is practically healed. In the lateral portion of the lower femoral metaphysis is a somewhat cystic appearing area of decreased density, occupying a subcortical location and causing a distinct expansion with marked thinning of the overlying cortex. A portion of the lateral margin of the mass seems devoid of cortical covering. Surrounding the mass, excepting the lateral portion, is a ring of increased density (calcification). This entire area is separate from the epiphyseal line.

Roentgenographic studies were made of these bones two years later (Fig. 11). The site of the previous fracture is not demonstrable. No evidence of rickets is seen and the "rachitic inclusion" has disappeared.

An analysis and interpretation of the roentgenograms in this case are of importance in this paper. The rachitic process was well healed after fifty-two days of active antirachitic treatment, as was the fracture after a similar period of immobilization. The point of interest is the somewhat cystic appearing area of decreased density found in the lower femoral metaphysis after fifty-two days of treatment. Because of the location of this area and the peripheral ring of calcification about it, it undoubtedly is a cartilaginous inclusion. The expanded, thinned, and partly absent cortex overlying the mass suggests that the cartilage in the inclusion had been proliferating with extension into and even beyond the cortical region. Roentgenograms taken two years later showed that replacement and effacement of the mass by ossification had occurred. Had calcification and ossification of this cartilaginous inclusion not occurred, it might well have served as the nidus for either a cartilaginous exostosis or a chondroma.

Virchow[1] thought that cartilaginous inclusions which persisted in the spongiosa following rickets might lead to the formation of enchondromata (central chondromata) and if they persisted in the compacta might lead to ecchondromata. Flinker[14] believed that he could trace cartilaginous exostoses back to rickets. Also, he considered dwarfism, cretinism, and gigantism important as etiological factors. Meyerding[15] studied a series of 265 exostoses in 232 patients and concluded that heredity and metabolic disturbances in childhood are more important and trauma less important than the histories of his patients would indicate. Honeij[10] thought that an exostosis could result from periosteal growth stimulated by injury, while Sudler[16] believed that trauma was important in the formation of cartilaginous tumors.

Haas[17], in discussing the etiology of ecchondromata, stated that rickets may be the exciting agent. He also mentioned that in some cases of enchondroma trauma, misplaced islands of cartilage, and rickets are all important etiological factors. Wagner[18] considered injury important in the formation of enchondromata of the pelvis.

From experimental information, Helmholz[19] believed that a chondroma might result from stimulation of perichondrium or connective tissue with a transformation into cartilage.

Geschickter and Copeland[20] state that cartilaginous tumors take origin from blastemic or precartilaginous connective-tissue remnants. Thus they explain chondromata as originating from a persistence of this tissue, which, through a failure of mucoid regression, is responsible for origin later of cartilaginous islands in the bone from which these tumors arise. According to these authors, single exostoses may occur as the result of trauma to a normal cartilaginous growth zone or where aberrant strands of blastemic tissue have been left behind to form embryonic cell

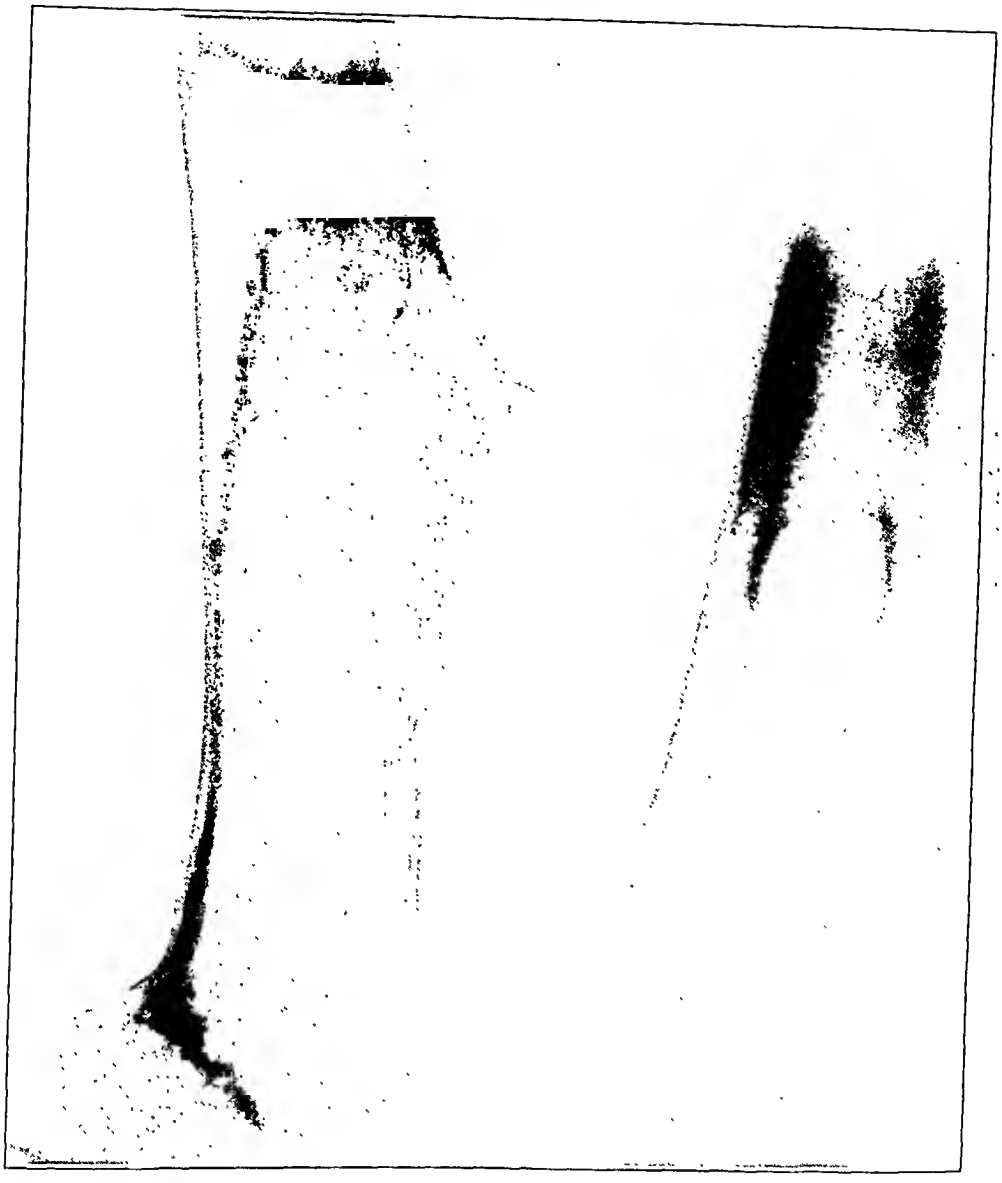

FIG. 12

Cartilaginous exostosis of the femur occurring apparently as the result of direct trauma.

rests. They state that an imbalance in growth of a normal bony protuberance, intended for the anchoring of an important tendon, and persisting precartilaginous connective tissue in the tendon end will lead to the formation of an osteochondroma.

Only as rachitic inclusions might be related to the formation of chondromata and exostoses would rickets have any relation to the development of malignant tumors of cartilage. Malignant degeneration of a cartilaginous exostosis occurs occasionally[21]. A chondroma may lead to a malignant neoplasm, according to Geschickter and Copeland[20]. They assume that neoplasms arising in the periphery of a bone have their origin in embryonic or cartilaginous rests. They do not mention the metamorphological phenomenon, pointed out by Phemister[21], that tumors

arising about the periphery of the bone often go through the fibrous, cartilaginous, and osseous stages, just as does peripheral callus in the healing of a fracture. Phemister believes that the finding of cartilage in the outer portions of the tumor is no more a sign that the tumor arose from cartilage than is cartilage in the same region of a callus a sign of its cartilaginous origin.

That certain benign cartilaginous tumors may take origin from a persistence of strands or a nest of precartilaginous connective tissue, as shown by Geschickter and Copeland[20], is not questioned, but it seems doubtful that all cartilaginous tumors arise from such an embryonic rest. It appears that other factors and conditions are responsible for the development of some of these tumors. Rickets, giving rise to islands of cartilage, containing a proliferating type of cell, which persist even after healing has occurred, cannot be entirely ruled out as an etiological factor in certain cases in the formation of benign cartilaginous tumors, especially chondromata.

Trauma is often mentioned by patients as the exciting cause for bony tumors. This is undoubtedly the factor that calls the attention of the patient to an unrecognized preexisting tumor in a number of cases. In many cases, however, there is a definite history of injury preceding the appearance of a tumor and it does not seem possible to disregard this factor entirely. Kleinberg[22] reported a case of periosteal chondrosarcoma in the upper end of the tibia in a nineteen-year-old boy, in which he thought trauma was the inciting cause. Figure 12 shows roentgenograms of an exostosis of the femur in an interesting case.

This patient, a white male, twenty-four years of age, entered the Los Angeles County General Hospital in November 1933. Eight years previously he had injured the same region in a fall. Sometime later he noticed a swelling which grew slowly for approximately four years, remaining stationary after that. Pain around the swelling caused him to seek some relief. This pain was explainable by an overlying inflamed bursa discovered at operation when the bursa and tumor mass were excised. The exostosis was not at a tendinous insertion. There was no family history of similar tumors. The patient presented neither history nor physical evidence of previous rickets. There had been no serious ailments of childhood or adolescence. The pathological studies of the excised tumor revealed typical gross and microscopic findings of a cartilaginous exostosis.

In this case, as far as could be determined, trauma seemed to be the exciting cause of the growth. It seems unnecessary and depends too much on an element of chance to assume that a rest of blastemic or precartilaginous tissue would have had to be present at the point of injury to cause this tumor, as claimed by Geschickter and Copeland[20]. Metaplasia of the connective-tissue elements found normally in the structures surrounding bone might account for the formation of cartilage and bone, in the same way that these elements, stimulated by the trauma of a fracture, lead to the formation of cartilage in the peripheral callus and subsequently to the formation of osseous tissue. Mallory[23] has recently pointed out the metaplastic properties of fibrous-tissue elements in the formation of tumors of soft parts containing bone and cartilage.

SUMMARY

1. Cartilaginous inclusions in the epiphyses and metaphyses of the long bones, as well as in the ribs and vertebrae, were found at autopsy in a case of healed rickets.

2. These inclusions, although fairly numerous, showed only faintly in the roentgenograms; hence such inclusions might easily be overlooked in clinical roentgenographic studies of rickets.

3. In experimental work on rats, cartilaginous inclusions were found in the metaphyseal, epiphyseal, and cortical regions of bone in cases of healed rickets.

4. Microscopic studies revealed that calcification was taking place in many of the inclusions. A few, however, appeared to be "latent" with slight, if any, evidence of calcification, and contained cells somewhat similar to those seen in a normal zone of proliferation in an epiphyseal plate. This proliferating type of cell in these rachitic inclusions might possibly serve as the "nidus" for benign cartilaginous tumors of bone.

5. In the case of fracture and rickets presented, the roentgenograms, taken after healing had occurred, showed a large expanded circumscribed area in the cortical region of the lower metaphysis of the femur suggestive of a rachitic cartilaginous inclusion. This had disappeared two years later.

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THE TREATMENT OF FRACTURES OF THE OS CALCIS

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The advocation of any new plan of management for fractures of the os calcis almost demands, as a background, the presentation of an introductory review, considering the average lost time and the amount of final disability resulting from both the new method and all previously accepted programs of treatment.

Two years ago such a compilation was begun and only recently reluctantly abandoned for reasons peculiar to the present economic upheaval. The majority of these unfortunate patients are or were wage earners but, whereas in the past suitable sedentary or light employment was readily available following recovery, the industrial retrenchment and wide-spread unemployment has made it impossible for many of them to find any type of work. A few remarkably honest patients have admitted full recovery, but the majority have demanded and received State compensation or, in many instances, what amounts to prolonged unemployment insurance, based upon allegations of vague but constant pain. As an example, one patient, following a severe unilateral fracture, returned after eleven weeks to an occupation requiring thirty hours a week on a concrete floor; in addition he continued as a week-end golf caddie for seven months without pain or complaint. The advent of winter stopped both activities, but incited sudden disabling and violent pain which continued unabated for five months, when permanent reemployment effected immediate relief. Certainly the presentation of statistics so distorted can be of no practical value.

TYPES OF FRACTURES

It is nevertheless imperative to statistically identify the character and the incidence of the type of fracture here considered and possibly the following personal series will be accepted as reasonably representative of the general experience. If so, it will be noted that approximately 85 per cent. of all fractures of the os calcis are of the squash type, presenting some degree of upward displacement of the tuberosity with eversion and lateral expansion (Fig. 1). This type, by reason of the displaced lateral bone, usually evicts the peroneal tendons from their normal grooves and not infrequently causes impingement between the os calcis and the external malleolus.

A total of seventy-four patients presented eighty-three fractures of the os calcis, nine being bilateral lesions. Seven patients presented unilateral, inconsequential chip or incomplete fractures, capable of spontaneous and complete repair. The infrequent avulsion type of lesion was found four times. Twenty-six lesions were ancient, the remainder were fresh or of less than two weeks' duration. Four of the nine bilateral cases were ancient, the remainder fresh. In two of the fresh and one of the

ancient bilateral cases radical interference was refused, as it was also in one fresh and one ancient unilateral case. It will be noted that where operation was indicated the refusal rate was approximately 9 per cent. In at least four of these cases the refusal was attributable to extraneous medical advice, apparently obtained from sources particularly unfamiliar with the disabling character of these lesions, a clear indication for an educational campaign.

Deducting from the total of eighty-three fractures seven trivial lesions and four fractures of the avulsion type, there remain seventy-two fractures presenting the squash type of lesion with disruption of the tuber angle and lateral expansion of the tuberosity. It is this group with which we are hereafter solely concerned. The twenty-six ancient lesions all presented pronation of the heels, planus of the long arches, and valgus of the forefeet with persistent disabling pain. Uniformly the patients complained of a high loss of lateral motion, pain characteristically referred anterior to the subastragalar joint, usually to the dorsum of the foot in

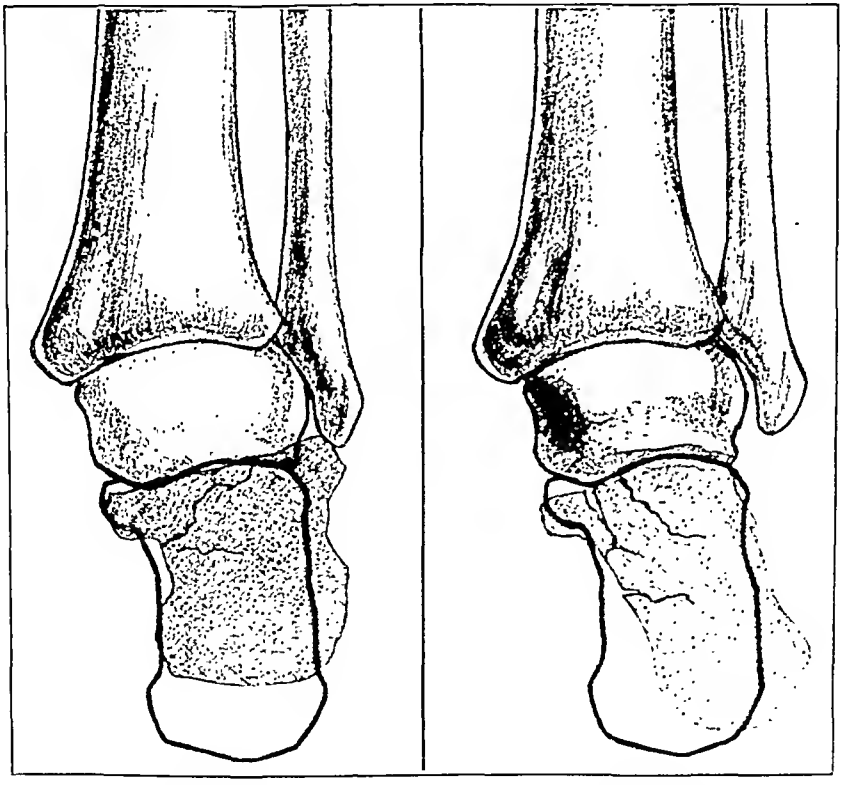

FIG. 1-A

Schematic posterior view showing a typical fracture with eversion and compression of the tuberosity (squash type). Note the untoward bone impinging on the external malleolus.

FIG. 1-B

Shows a typical fracture with eversion of the tuberosity of the os calcis. Note the depression and fracture of the sustentaculum tali in each lesion.

front of the external malleolus and to the sole of the foot in the region of the hollow of the long arch. Peroneal spasm was a constant finding. As previously noted, five patients with eight lesions refused treatment, so that the total number of treated fractures is reduced to sixty-four.

These readily fall into four distinct groups:

1. Thirty-nine both early and late lesions, treated by subastragalar arthrodesis with or without Magnuson's regrooving for the peroneal tendons;

2. Five fresh fractures, treated by combined forcible lateral compression and skeletal traction;

3. Fourteen fresh cases, treated by a two-stage program of lateral compression and skeletal traction, followed five weeks later by combined subastragalar, astragaloscaphoid, and calcaneocuboid fusion;

4. Six ancient lesions treated by this same triple fusion.

Unfortunately, as has been explained, exact conclusions regarding the end results from these various procedures are now impossible. Generalities may indeed glitter, but they need not be willfully deceitful, and they probably here reflect a fairer picture than the patient's own estimate of his final disability, tinctured as it usually is by a desire for the greatest possible permanent disability award, and embittered as he often is by early mistreatment and subsequent unemployment.

LIMITATIONS OF SIMPLE FUSION

Simple subastragalar arthrodesis failed to yield satisfactory feet in at least one-third of the fresh and in certainly one-half of the late lesions in this series. This might have been anticipated, had we fairly considered its limitations. To be sure, it relieves attrition in the disrupted subastragalar joint and offers something toward the correction of the eversion of the tuberosity and the flattening of the tuber angle, but conversely it aggravates rather than relieves any existing foreshortening of the tuberosity, because of the additional bone loss incident to the joint excision; and it does nothing to correct the malalignment of the neck and head of the astragalus in relation to the scaphoid. Further, the eversion if severe is hard to correct by subastragalar arthrodesis, because of the technical difficulty of cutting a bony wedge with the base in the depth of the wound.

In searching for all of the causes contributing to the high percentage of unsatisfactory results from this operation, it was observed that in about 8 per cent. of the patients bony fusion was either doubtful or absent. Curiously enough this same failure to secure bony fusion was present in approximately an equal percentage of the satisfactory feet. The logical deduction seems to be that fibrous union frequently follows the operation, and that it is not necessarily the explanation as to why protracted disability exists. The major cause of failure was next attributed to the unreduced upward displacement or shortening of the tuberosity; therefore, Böhler's program of lateral compression, followed by direct skeletal traction to restore the tuber angle, was welcomed. Nevertheless, information

was sought as to how such allegedly excellent results could be obtained in the presence of a roughened and distorted inferior subastragalar joint surface, and the assurance was received that the restoration of the tuber angle and the secondary correction of any eversion reduced the destructive serration in this joint, thus obviating the necessity for any open interference.

The construction of the ill-fated Zeppelin "Akron" offered an opportunity for the treatment of five lesions under ideal conditions. They were subjected to Böhler's treatment meticulously applied, but the final results were indifferent. The general contour of the feet was distinctly improved; however, the residual lateral motion was limited and always painful. A succession of roentgenograms indicated the slow but steady disintegration of the normal subastragalar-joint cartilage, associated with a progressive increase in pain and lameness.

The fifth of these patients suffered a mild fracture of the squash type with only slight upward displacement of the tuberosity and with no visible fracture lines entering the subastragalar joint. Six weeks after reduction he presented an almost complete loss of lateral motion with peroneal spasm and mid-tarsal pain on weight-bearing. This unexpected result, following four previous disappointments, was not long deliberated; on the contrary, the subastragalar joint was surgically explored. Notwithstanding the mild character of the initial lesion, the restoration of the tuber angle, and the absence in the early roentgenograms of visible fracture lines involving the subastragalar joint, the cartilage presented astonishing

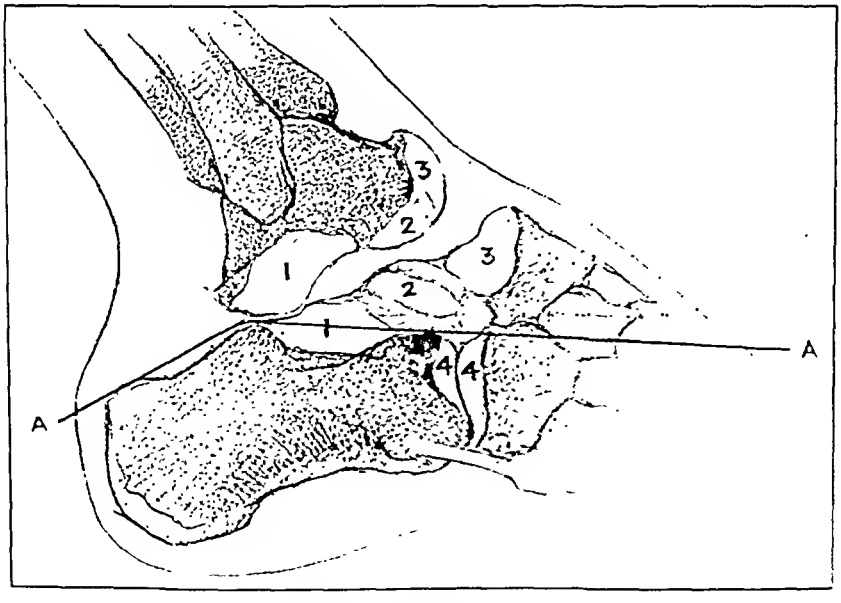

FIG. 2

The astragalus tilted to permit visualization of the reciprocal articulating cartilages. The corresponding numerals indicate the surfaces normally apposed.

roughening and erosion. This finding was not easy to accept but, hoping that it might be the explanation for the protracted pain in the four previously treated fractures, they were promptly explored, and in none was there anything like satisfactorily smooth apposing surfaces (Fig. 2). This, however, was not the whole story.

In 1929, the writer described occasional lesions of the os calcis, presenting fracture lines extending into the calcaneocuboid articulation, and suggested that these fractures be treated by arthrodesis. It had been observed that these lesions untreated gave rise to persistent pain, but the cause was erroneously considered to be non-union of the fragments rather than the much more obvious roughening of malalignment of the apposing articular surfaces. This joint, it will be recalled, underlies the familiar site of chronic pain, particularly in the ancient and untreated cases, while the next most familiar site of pain,—namely, the hollow of the long arch—underlies the astragaloscaphoid joint. Having unexpectedly found disruption of the subastragalar joint, unrevealed by the roentgenograms, these later articulations fell under suspicion and were at first hesitatingly fused. The expected roughening and erosion were not often observed; the final results, however, were distinctly better. Apparently from false premises a logical conclusion had been drawn.

ANATOMY

In seeking the real explanation for the improved results, a particular anatomical study was necessary for which grateful acknowledgment is made to Dr. MacEwen. However, before considering the normal architecture, certain phases of the wreckage incident to crush fracture must be understood. The operative findings had constantly revealed disruption of the subastragalar joint and depression of the sustentaculum tali wherever there had been palpable thickening of the tuberosity of the os calcis or any limitation in the normal range of motion,—this despite roentgenograms frequently negative for joint involvement. Just why so much faith was formerly placed in the roentgenographic examination is difficult to explain, when obviously eversion of the os calcis with inward rotation of the astragalus could not exist without fracture. The apposing joint surfaces are flat; therefore, if rotary displacement occurs, something must yield and this will usually be the weak shelflike sustentaculum tali.

Depression of the sustentaculum tali is here stressed because, as will be explained, it offers the most logical explanation for many of the therapeutic failures (Fig. 3). It has already been intimated that much of the late pain and disability may be attributable to difficulty anterior to the subastragalar joint, but this is not as contradictory as it seems, for the anatomical study has shown that *depression of the sustentaculum tali permits subluxation of the astragaloscaphoid and calcaneocuboid joints.*

Recalling the familiar construction of the long arch of the foot, in which the posterior pillar is the tuberosity of the os calcis and the anterior pillar the metatarsal bones, it will be observed that the astragalus rides

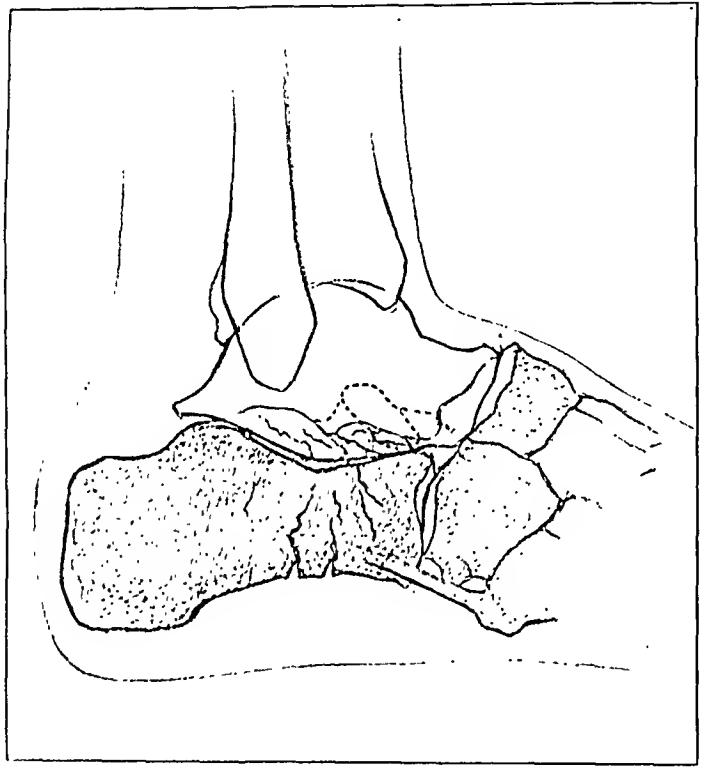

FIG. 3

The astragalus drawn in phantom to permit visualization of the reciprocal articulations. The normal position of the sustentaculum tali is indicated by the dotted oval. Note the flattening of the tuber angle, the descent of the sustentaculum tali, and the resulting subluxation of the calcaneocuboid and the astragaloscaphoid joints.

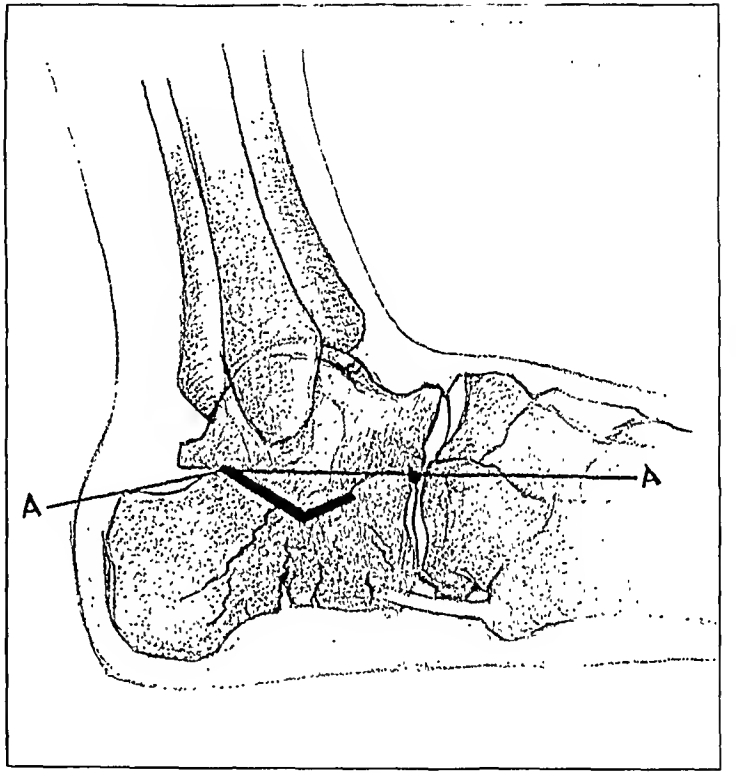

FIG. 4

The dark angular line indicates the area of additional bone loss incident to subastragalar fusion. Note the unsupported astragalar head and neck and the uncorrected malalignment of the astragaloscaphoid and calcaneocuboid joints.

the summit of the arch, walking beam fashion. The term "arch" is apparently a misnomer, for the essential Roman keystone is absent. It is more nearly a laminated bow, broken in the middle at the astragaloscaphoid and calcaneocuboid joints, articulations which physiologically act as reciprocating units. Anatomically, although not presenting communicating synovial cavities, the two joints usurp the whole transverse diameter of the bony foot and are functionally coordinate. They present a saddle-like articulation on the scaphocuboidal aspect, into which is thrust the ovoid contour of the combined astragalar head and anterior articulating surface of the os calcis. Piersol says these joints are not of the true ball-and-socket type, but permit only a screwlike activity and absorb the forward thrust of weight-bearing as transmitted through the tibia to the astragalus and secondarily to the os calcis. He later considers these joints as entities and concludes that the stresses absorbed through the astragaloscaphoid articulation are those transmitted to and through the first and second metatarsal bones, while those of the third, fourth and fifth metatarsals are transmitted to the calcaneocuboid joint. The deep posterior or inferior capsules of these two major mid-tarsal joints are reenforced by blended reduplicating bands or fibers known as the deep plantar ligaments. These fibers permit an interesting physiological mobility viewed in a dissected foot, yet are the first line of defense against any disruption of the normal anatomical relationship.

Further complicating the structural problem involved, is the surgical continuity of the subastragaloid and astragaloscaphoid articulations. Crossan attributes this observation to the late G. G. Davis who taught that subastragalar fusion without contemporary astragaloscaphoid fusion was unsatisfactory and unsound. He considered the two articulations despite their independent synovial compartments as a single physiological unit and as such to be always subjected to combined surgical attack. Although this idea was only applied to juvenile deformities, the conclusion is equally applicable to the derangements occasioned by fracture. With the observations of Piersol and Davis the writer completely concurs, and he believes that they furnish a valuable clue to the reason for the frequent failure to obtain painless feet by simple subastragalar fusion.

Attention is called to the fact that the central portion of the astragalus is clearly supported or balanced on a facet articulating directly with the sustentaculum tali, while the posterior extremity articulates with the posterior articulating surface of the os calcis—these two being usually considered as the true subastragalar joint; the head of course articulates with the scaphoid. We have already observed the absence of a rigid arch and should further note the hinge or cart-spring type of construction in which resiliency is obtained by a basal calcaneocuboid metatarsal arc whose center is hinged by the deep plantar ligaments and whose extremities are prevented from extension by the bow-string action of the superficial plantar ligaments and fascia. Rupture of these last structures has never been observed; hence the violence is expended at the major hinge,

with resulting bony distortion and dissolution of the deep capsular tissue and ligaments. Fracture lines then invading the subastragalar joint and

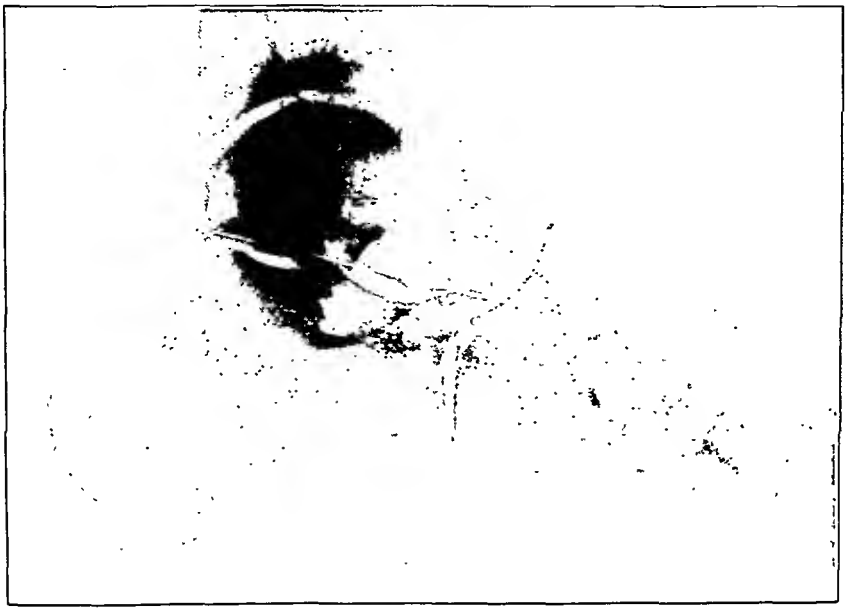

FIG. 5-A

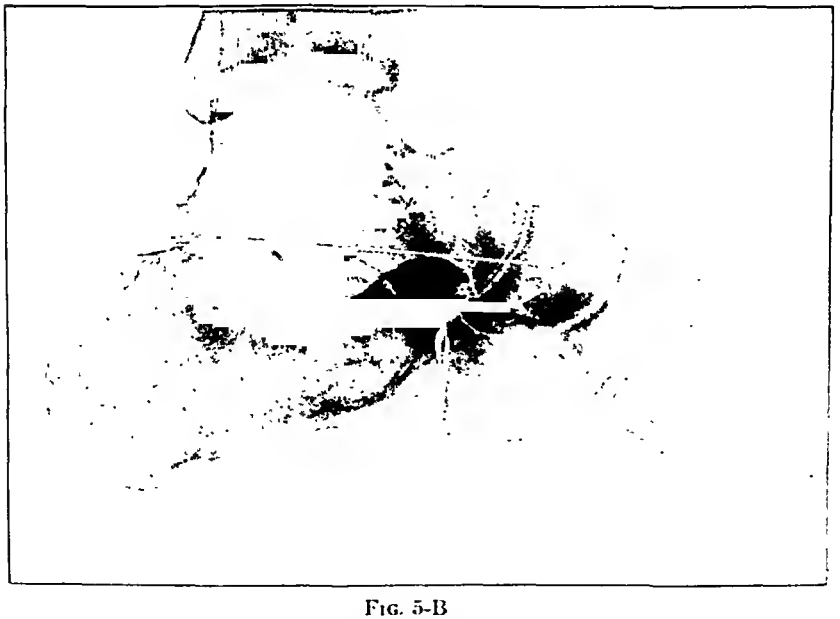

FIG. 5-B

Typical lateral roentgenograms showing (Fig. 5-A) normal left foot, and (Fig. 5-B) ancient squash fracture of the right os calcis of moderate severity. Note the flattening of the tuber angle, the disrupted calcaneocuboid astragalar junction and the astragaloscaphoid luxation.

depressing the sustentaculum not only distort the posterior column of the long arch and induce unbearable strain upon the superficial plantar ligaments, but are responsible for malalignment of all the reciprocal articulations of both the calcaneum and the astragalus.

Returning to a consideration of the mechanical faults inherent in a simple subastragalar arthrodesis, it will be noted that it only accomplishes repair of the damaged posterior pillar, offering no relief for the equally serious major mid-tarsal joint distortion, and it in no measure relieves the strain upon the damaged deep plantar ligaments (Fig. 4). The interrelation, both functional and structural, between the subastragalar and the astragaloscaphoid joints is so close that, where the sustentaculum tali is depressed and its fulcrumlike function destroyed, a fixation of the posterior extremity by fusion is an obvious mistake. Further mechanical strain is invited by this operation which fastens one end of the astragalus springboard fashion, while the other is allowed to extend unsupported and misaligned forward to endure the body weight (Fig. 5).

With these facts appraised, multiple fusions routinely done to include the subastragalar, the astragaloscaphoid, and the calcaneocuboid joints seem not only logical but conservative. Thoroughly done, the operation eliminates the os calcis, the astragalus, the tarsal scaphoid, and the cuboid as entities, and produces one solid bony mass with an unvarying predeterminable functional loss. All lateral ankle motion is eliminated, but this is scarcely a demerit, since untreated these fractures result in an almost similar loss to which is added persistent pain, particularly severe where a few degrees of motion are retained. The rotary mobility and the slight anteroposterior flexibility at the combined calcaneocuboid and astragaloscaphoid articulations is also sacrificed, but again the same considerations prevail as with the loss of lateral mobility. The initial violence will usually have so seriously disrupted these joints that treated expectantly a high degree of lost function will prevail, while any residual motion will serve as a source of enduring pain and disability. In fact, these few remaining degrees of lateral and mid-tarsal motion in the unfused cases furnish the only explanation for the constant pain and prolonged disability noted by every author in the bibliography. Fortunately the extreme rigidity following triple fusion is transient. A month or six weeks of active weight-bearing induces a gratifying compensatory mobility in the anterior tarsal joints, so deceiving that in the early cases the success of the fusion was doubted.

Among the benefits of triple fusion must be listed the positive restoration of the normal contour of the foot and the permanent preservation of the long arch. To these should be added the correction of any eversion of the tuberosity and the elimination of untoward bone encroaching upon the peroneal tendons or the external malleolus.

TREATMENT

In developing the present plan of treatment, the final results have

strongly indicated the fallacy of permitting weight-bearing in the period between the initial reduction by extension and the secondary triple fusion. This converts the fresh lesion into an ancient one and invites not only pathological but psychological inhibitions. The necessity for a two-stage operation is always explained to the patient. The first stage is completed as soon as the initial hematoma has at least partially disappeared under a compression bandage; this usually occupies two to four days.

At the primary operation a heavy wood clevis with interchangeable jaws, one set kidney-shaped, the other cylindrical, is used for the compression and manipulation. Compression alone is not adequate; the tuberosity must be firmly clamped and rocked in order to break up all existing impaction. Thereafter, steel transfixion pins are inserted through the lower tibia and the tuberosity of the os calcis as recommended by Böhler. Several ingenious methods for accomplishing extension have been published, all with a measure of merit; none, however, have been entirely adequate in their ability to correct both the upward displacement

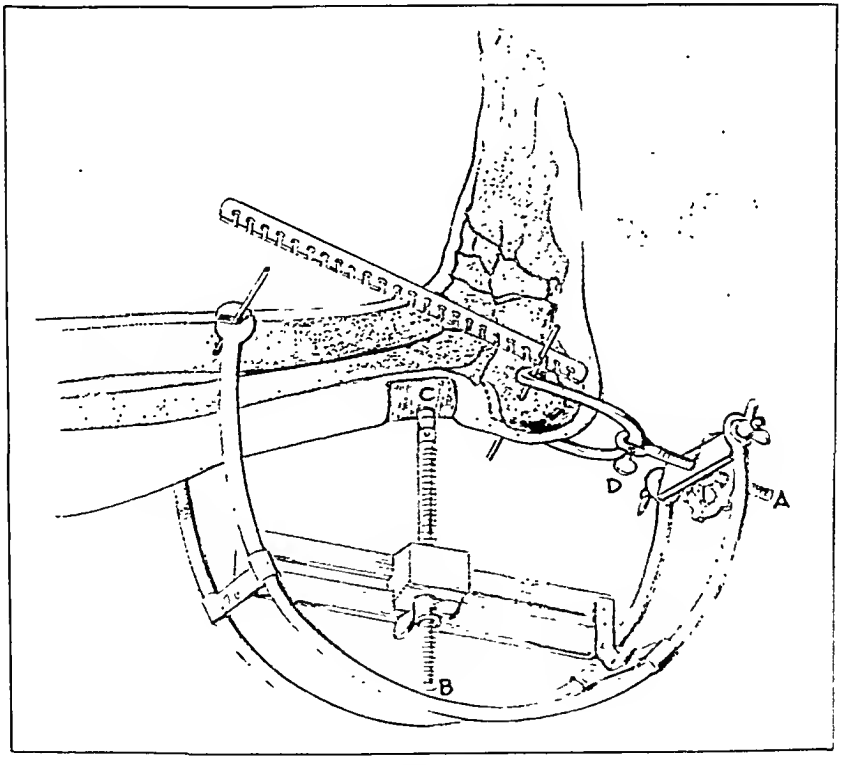

FIG. 6

Sketch of the author's traction apparatus for reduction of the upward displacement and the foreshortening of the tuberosity of the os calcis. Positions of the transfixion pins are shown, also the slotted metal strips, two of which are incorporated in the plaster cast to fix the extension. *A* indicates the extension mechanism; *B*, the elevating screw; and *C*, the heel rest. *D* indicates the sliding arc, permitting control of the position of the heel.

and the foreshortening of the tuberosity. Since these two deformities are usually coexistent and both of serious import, the apparatus shown in Figure 6 was evolved. With this device, the correction is most efficient if strong downward traction is first made by tightening the extension screw. This widely separates the two transfixion pins and places the site of fracture under tension. The heel rest or fulcrum is then forced sharply upward, without relaxing the extension; and the resulting strain will induce posterior elongation. The lower caliper is adjustable, so that the heel may be properly inverted during the process of reduction and no elaborate care need be taken to insert the lower pin in exactly the right plane. A well padded cast is then applied, beginning below the knee and extending to the toes. Originally the cast was closely applied about the pins, but it was noted that, unless several hours were allowed to elapse with the extension apparatus in place, the relief of tension incident to the removal of the apparatus allowed a considerable loss in the forcibly acquired extension. This was overcome by thin, slotted, metal strips which, just before the completion of the cast, are slipped over the pins and incorporated in the cast by additional bandages. The cast is then cut away to permit the removal of the heel rest and the resulting defect repaired by the application of a bandage.

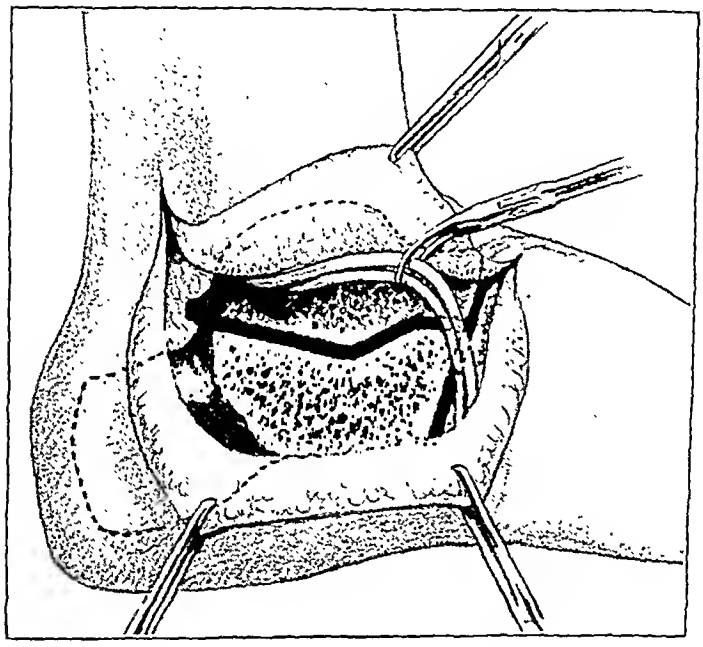

FIG. 7.

The operative exposure. Note the area of cancellous bone exposed by the removal of the thin cortical plaque and the resulting easy identification of the joint margins. The heavy dark angular lines indicate the extent of the fusion.

The attempt to apply unpadded plaster yielded nothing but trouble. Generally a considerable reaction follows the application of compression and the manipulation, so that the resulting swelling necessitates splitting and loosening of the cast, always difficult in the absence of padding. Since there is no valid reason for the application of an unpadded cast, a generous amount of sterile sheet wadding is applied and the cast is split in anticipation of trouble. The incorporated metal strips obviate any concern about the loss of reduction, if necessity demands that the cast be widely spread. Four weeks have proved to be ample for the development of sufficient early callus to maintain the reduction. At the expiration of this period

the cast and pins are removed and a week, sometimes a few days more, is allowed for the healing of the pin holes.

At the end of this period the second operation is done. The most satisfactory incision has been an L-shaped one, begun roughly two inches above the external malleolus and just behind the posterior border of the fibula, extended downward to encircle the malleolus, one inch below the tip and carried forward and upward to end over the astragaloscaphoid joint (Fig. 7). The peroneal tendons are freed but not divided and retracted upward. The incision is widely retracted, and the lateral surface of the tuberosity, as well as the anterior portion of the os calcis, is freed of soft tissue. A thin, wide osteotome is used to remove a waferlike plaque of bone and periosteum from the lateral surfaces of both the os calcis and the astragalus. The thinnest possible plate should be lifted, turned forward and upward in such a manner that the subastragalar, the astragaloscaphoid, and the calcaneocuboid joints are all traversed, their cartilaginous markings standing out in sharp relief against the exposed cancellous bone. This is of material help, particularly in the old lesions where the normal joint lines have been partly obliterated. In practically all of the cases, despite compression, manipulation, and forcible extension, there has remained an untoward bone mass on the lateral surface of the os calcis. Continuing with the thin osteotome, this bone is removed and preserved, if possible in one single slab, the thickness varying from three-sixteenths to five-sixteenths of an inch. In several instances it has been necessary to make a short second incision over the dorsum of the foot to completely expose the astragaloscaphoid articulation. This second incision possibly renders the operation easier, but complicates the technique. The removal of the several joint cartilages is purely a routine procedure. The raw and apposed bone surfaces are roughened with a small gouge and the previously preserved heavy bone plate is split into shavings which are packed principally in the proximity of the subastragalar joint in such a manner as to change the existing eversion, if any, into inversion. Any remaining chips are packed into the astragaloscaphoid and the calcaneocuboid joints. The waferlike plaque first removed has been sometimes discarded and sometimes replaced. Originally it was thought imperative to restore this periosteum and cortex, but apparently there has been no difference in the healing or in the amount of time required for the appearance of bony ankylosis. The peroneal tendons are replaced and the wound closed. The postoperative cast is loosely applied and well padded, but molded to secure proper inversion of the heel and to preserve the curve of the long arch.

At the expiration of three weeks, without anaesthesia, the first cast is removed, the wound is inspected, and a second snug, thinly padded cast applied. In one case union was too firm to permit any refinement in position, but usually it will be found easy and desirable to slightly change the inversion, the varus, or the curve of the long arch. Also, at this time, it is usually possible by manipulation to make an accurate estimate as to how long the newly applied cast need be worn. In the majority of the cases,

this second cast has been bivalved at the end of two weeks, and thereafter removed daily for physiotherapy. Weight-bearing is usually allowed eight weeks after the second operation; in two cases it was begun on the fifth week, and in one case it was delayed until the end of the eleventh week.

The subsequent after-care has been extremely simple. Whereas with subastragalar arthrodesis alone, the Whitman foot plate was prescribed; following the triple fusion, only a high shoe with a rigid shank and a Thomas heel has been required.

COMMENT

In sponsoring a program so complicated, it is impossible to be unaware of the inevitable criticism which must follow its ill-advised application by those unwilling to follow a rigid technique and those unfamiliar with the complicated structure involved. It has, nevertheless, proved infinitely more efficient and is more rational than a simple subastragalar arthrodesis which ignores at least half of the anatomical derangement in the severer types of squash fracture.

Two years ago, in a personal interview, the lay chief of the Industrial Commission of Ohio, after an extensive experience with subastragalar arthrodesis in the treatment of these fractures, asked in all seriousness, why surgeons did not recommend amputation? Such an inquiry is probably as illuminating and more pertinent than an exhaustive statistical review.

Treatment by manipulation, traction, and triple fusion has now been extended to include nineteen fresh fractures in which the results have been excellent in all but two instances. Six ancient lesions have been subjected to triple fusion with good results in all but one. Since the operation is technically difficult, it is probable that increased operative experience will lessen the failures.

SUMMARY

1. Manipulation, skeletal traction, and subastragalar arthrodesis have heretofore inadequately solved the problem presented by squash fractures of the os calcis.

2. The failure of these various methods of treatment can be explained on a rational anatomical basis, centering about depression of the sustentaculum tali, a lesion which cannot be certainly recognized by the roentgenologist. An operative exposure has frequently disclosed serious articular disruption, when the roentgenograms were nearly or completely negative for joint involvement.

3. We have come to consider any appreciable loss of lateral motion in the subastragalar joint, or the presence of thickening and untoward bone on the external surface of the tuberosity of the os calcis, as diagnostic of disruption of all of the reciprocal articulations of the calcaneum, irrespective of the roentgenographic findings.

4. Finally, a plan of treatment more completely correcting the extensive anatomical distortion has been evolved, which includes a prelimi-

nary reduction by manipulation and skeletal traction, to be followed five weeks later by subastragalar, calcaneocuboid, and astragaloscaphoid fusions. In dealing with the late lesions, where obviously traction could be of no assistance, it has not been attempted and the treatment has been limited to a primary triple fusion.

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THE INFLUENCE OF THE SHOE ON GAIT

As Recorded by the Electrobasograph and Slow-Motion Moving Pictures *

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In the method of making electrobasographic records described in previous papers [1, 2], the patient's own shoes were used. The prevailing differences in shoes and the changes induced by wear has caused us to regard them as a potential variable (Fig. 1-A). It was, therefore, desirable to determine the effects of different shoes as revealed by electrobasographic records. (See Figure 1-B.)

Controversy may be avoided by recognizing the fact that there is no agreement in regard to when a foot is normal with respect to its morphology. The paucity of data makes it still more difficult to define the normal with respect to function.

The difference revealed in the seven gait records (Fig. 1-A) was due to the prevailing characteristics of respective shoes worn by the same individual, Miss E. A. C. Although all of the shoes were comfortable, the records revealed a diminishing duration of weight-bearing on the fifth metatarsal head, which was most marked on the right foot and which was greatest with shoes having heels three and one-eighth inches high.

This observation was made in April 1933. The records indicated the presence of increasing instability of the feet, associated with increasing elevation of the shoe heel, as one known factor of importance. On April 14, 1934, two records were made with different pairs of shoes, the heels of which were two inches high. One pair (Fig. 2-A, R5026) was uncomfortable; the other (Fig. 2-A, Brogue No. 3) was comfortable; yet the gait records were both well within the normal limits when reduced to the average rate of walking. Both of these records are more normal than record W0063–4, made April 8, 1933 (Fig. 1-A), of a shoe with a heel two and one-eighth inches high. (See also Figure 2-B.)

These data indicate that electrobasographic records reveal the presence or absence of stability of the foot of a person wearing shoes of different heel height and construction. Pronation is revealed in the record by diminished weight-bearing time on the fifth metatarsal head. Improper fitting of the shoe, producing discomfort, is not revealed in the electrobasographic record until after the subject is unable to compensate for the pain produced. Moreover, heel height of a shoe cannot be accepted as the only shoe characteristic favoring the presence or absence of foot stability for a given person.

* Read before the American Medical Association, Cleveland, Ohio, June 15, 1934.

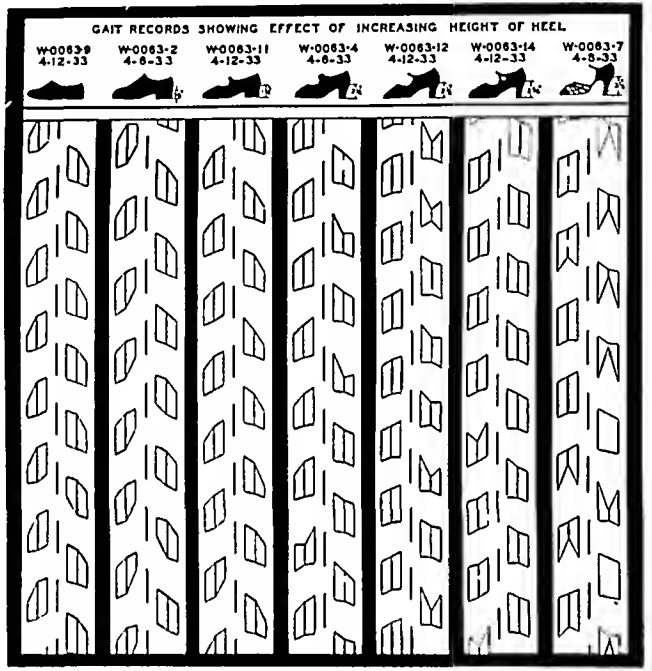

Fig. 1-A

Seven electrobasographic records of the same normal girl. Old shoes varied in last design, make, quality of material and workmanship. Heel height ranged from 0 to 3⅛ inches. Note electrobasographic evidence of diminishing weight-bearing time on fifth metatarsal head with increasing heel height, most evident in last record of right foot.

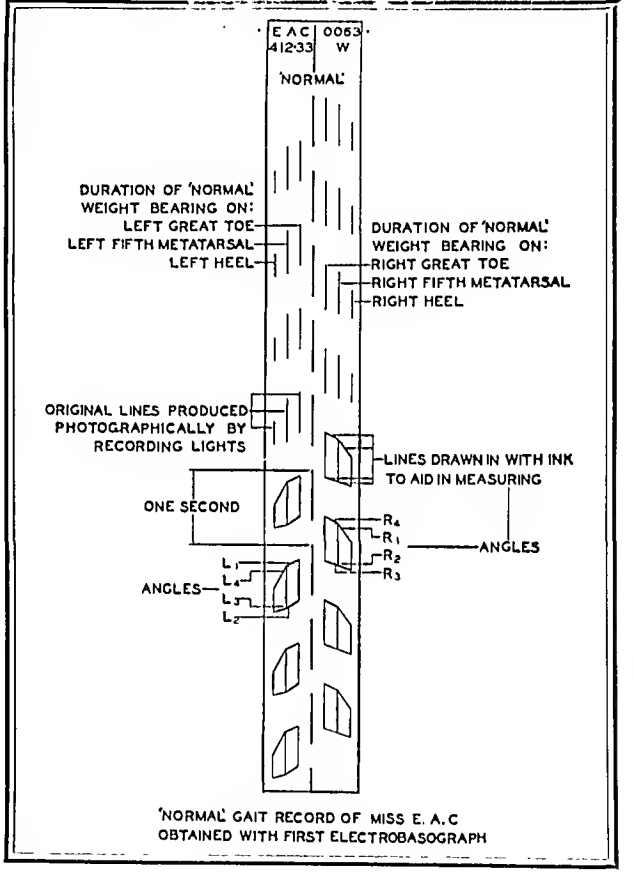

Fig. 1-B

Interpretation of original 70-millimeter electrobasographic record of "normal" gait.

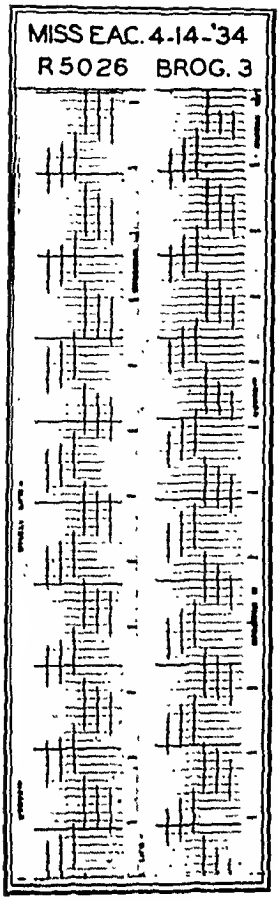

FIG. 2-A

Miss E. A. C., April 14, 1934. R5026 shoes too uncomfortable for use. Brogue No. 3 very comfortable. Both electrobasographic records revealed stability of respective feet and "normal" gait. Compare with Fig. 1, showing records of same "normal" person.

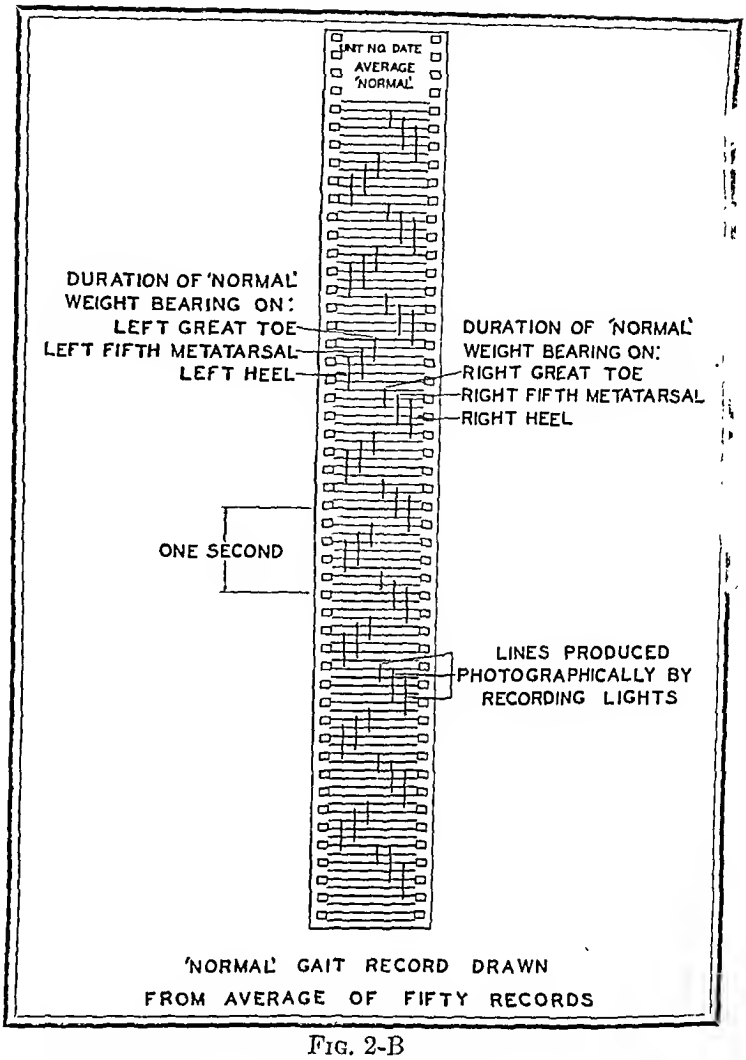

FIG. 2-B

Interpretation of present 35-millimeter electrobasographic record of "normal" gait.

It remained, therefore, to determine the effect of various types of shoes on other subjects. The two persons tested were women whose work had, for several years, required much walking daily between the hours of 9:00 a.m. and 5:00 p.m. They were, and had always been, free from any definite subjective symptoms in or referable to the feet, and the feet revealed no gross morphological changes.

With thirteen different pairs of shoes, divided into five groups, sixteen electrobasographic records were made of each of the two women mentioned. The method by which these records were made was as follows.

Figure 3 illustrates a 50-foot platform, covered with a cocoa mat, on which was placed 20-gauge galvanized sheet iron which was wired to the ground side of an A. C. circuit. One-half inch circular brass contacts were secured flush on the bottom of each shoe,—one over the heel, fifth metatarsal head, and great toe, respectively. Wires led from each of these

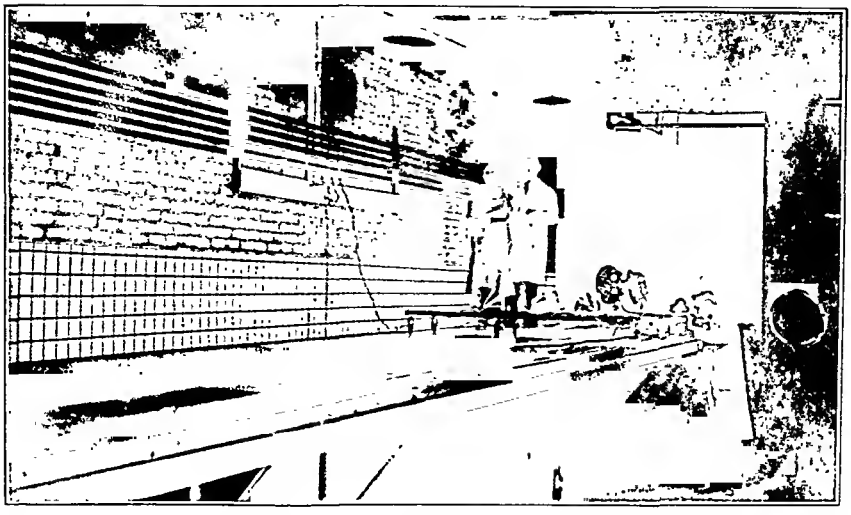

FIG. 3

Fifty-foot platform, showing motor-driven moving picture camera mounted on carriage used for following the subject while she walks the length of the platform.

contacts through a one-half-inch cable to both the 35-millimeter and the 70-millimeter electrobasographs. Thus, it was possible to make duplicate gait records (Fig. 4).

A carriage was mounted on a double track parallel to the platform. By keeping the subject centered on the 9 by 12 centimeter ground glass of a Recomar camera, it was possible, while following the subject, to make 16-millimeter moving pictures at 64 exposures per second with a motor-driven moving picture camera.

An extension was made from one end of this carriage to the middle of the platform. At this end, it was supported on four rubber-tired ball-bearing wheels which were six inches in diameter.

With the moving picture camera on the carriage, lateral views of each subject were made. When the motor-driven camera was moved to the extension on the middle of the platform (Fig. 5), pictures were made at a constant distance from front and back, while the subject walked the length of the 50-foot platform. A total of 7,000 feet of moving pictures was made, including right and left lateral views, front view with the subject walking toward the camera, and back view with the subject walking away from the camera. The rate of exposure (64 exposures per second), although four times better than normal (16 exposures per second), was found to be satisfactory only for the foot in the stance phase. Walking at the rate of 1.4 steps per second was unnatural, as compared to 1.8 steps per second. At this slower rate, which favored an unsteady gait, a sharp image of the foot in the swing phase could not be recorded at 64 exposures per second.

Sharp definition of the foot in the stance phase always revealed prevailing conditions which favored the production of abnormal gait records during the weight-bearing period on each foot.

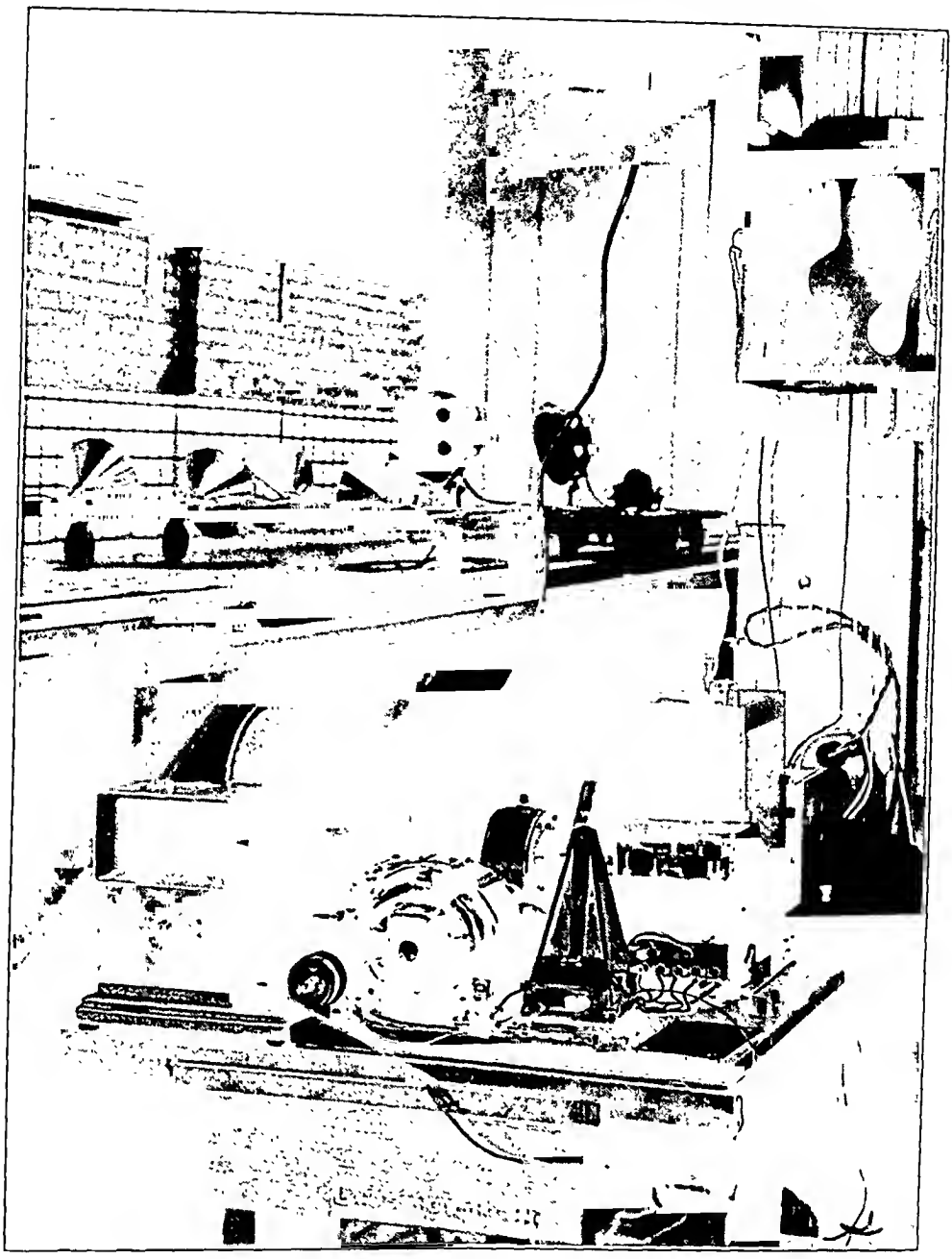

FIG. 4

Electrobasographs, 35-millimeter and 70-millimeter on left and right respectively. These were so wired that simultaneous gait records were made on the instruments.

The electrobasographic records revealed certain facts worthy of mention in relation to the present subject. The fitting of a shoe is usually considered in terms of the contour of the shoe with relation to comfort. Stability of the foot in a shoe had not been given consideration when the above criteria were found acceptable.

Group I included five pairs of shoes having certain last characteristics in common. They were identical in quality of workmanship and material, although the heel height was one and one-eighth inches, two inches, two

and one-eighth inches, two and one-quarter inches, and two and three-eighths inches. These shoes followed the contour of the feet and were comfortable on each of the two women tested. All five of the electrobasographic records were well within normal limits for Miss M. S. Three were likewise normal for Miss E. C. In Figures 6 and 7 and the accompanying charts, the differences in the records produced by these two women wearing the same shoes can be readily seen. Compare R5021 for Miss E. C. with R8009 for Miss M. S.

This evidence indicates that the relation of the contour of the shoe to that of the foot and the comfort of the foot in the shoe are objective and subjective requirements essential to the wearer. It further emphasizes that stability of the foot in a shoe is unrelated to the above criteria. Such instability may be more detrimental to the subject than foot discomfort from improperly fitting shoes. These two instances in ten records emphasize the necessity of paying attention to the shoe as a cause of inequality in duration of weight-bearing on the three respective points of each foot.

Group II included three pairs of shoes,—two of the same make and one of a different make, with heels two and one-quarter inches high on each pair. The criterion of fit was determined by contour of the shoes;

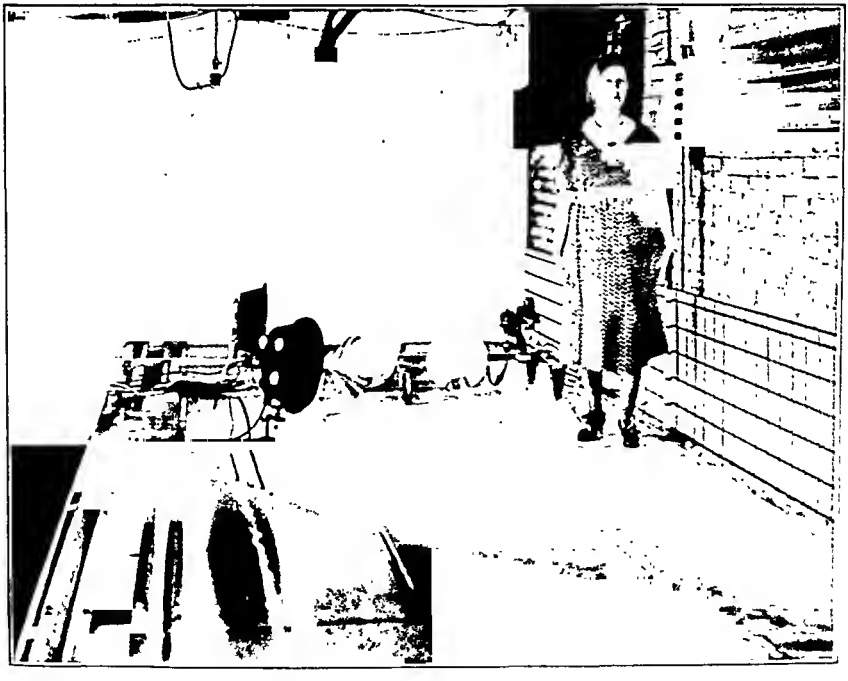

FIG. 5

Motor-driven moving picture camera mounted on platform extension from carriage. A satisfactorily constant distance is maintained when pictures are made while the subject walks toward and away from the camera.

each of the two subjects said they were comfortable. Shoes R5021 were used in this group; the records are abnormal as already mentioned. Both subjects were equally stable in eaeh of the other two pairs of shoes. Differenee in last design and quality of material and workmanship in shoes R8048 and D6413 were compatible with normal duration of weight-bearing on the three respective points of each foot as indicated by the electrobasographie records of the same two subjects. (See Figures 8 and 9.)

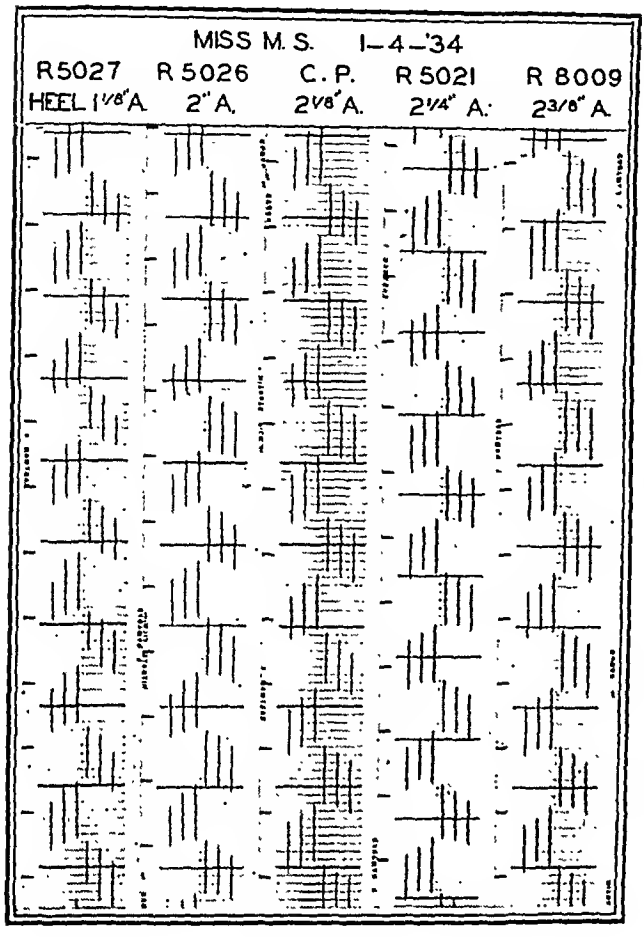

FIG. 6

Shoes worn by Miss M. S. when above records were made had in common quality of material, workmanship, and last characteristics, except for the changes in the latter which were essential for the indicated variation in heel height. All records reveal evidence of bilateral stability.

This investigation reveals that differences in the design of last may be definite, but the respective shoes may fit with comfort and provide stability for the foot under the influence of weight-bearing. Although new shoes of inferior quality and workmanship may be stable, they are more predisposed to the loss of this essential eharacteristic with increasing use and poor care.

TABLE (Fig. 6)

	Miss M. S. 1–4–'34									
Foot	R5027		R5026		C. P.		R5021		R8009	
Left heel	.60	seconds	.56	seconds	.61	seconds	.66	seeonds	.59	seconds
Left 5th metatarsal	.67	"	.66	"	.68	"	.64	"	.63	"
Left great toe	.70	"	.71	"	.71	"	.76	"	.75	"
Right great toe	.56	"	.71	"	.68	"	.74	"	.73	"
Right 5th metatarsal	.63	"	.66	"	.65	"	.68	"	.67	"
Right heel	.55	"	.61	"	.62	"	.67	"	.66	"
Time, left	.82	"	.83	"	.83	"	.84	"	.84	"
Time, right	.81	"	.81	"	.82	"	.85	"	.84	"

Above figures are for the average speed of 1.4 steps per second.

Group III included three pairs of shoes on the same two subjects. Two pairs differed in make, design of last, and quality of material and workmanship, with a heel height of one and seven-eighths inches and one and five-eighths inches, respectively. The third pair were the personal shoes of each subject with a heel height of one and one-half inches. Figures 10 and 11, together with the accompanying tables, reveal that both Miss M. S. and Miss E. C. had a short weight-bearing time on the heels and great toes with shoes D6989, while shoes R5027 and the personal shoes of each subject gave essentially normal records. Shoes D6989 were of proper size, but the last design did not provide for proper fitting at the heels; the loose heels slipped.

This investigation indicates that, although the size of the shoe may be correct and the foot may

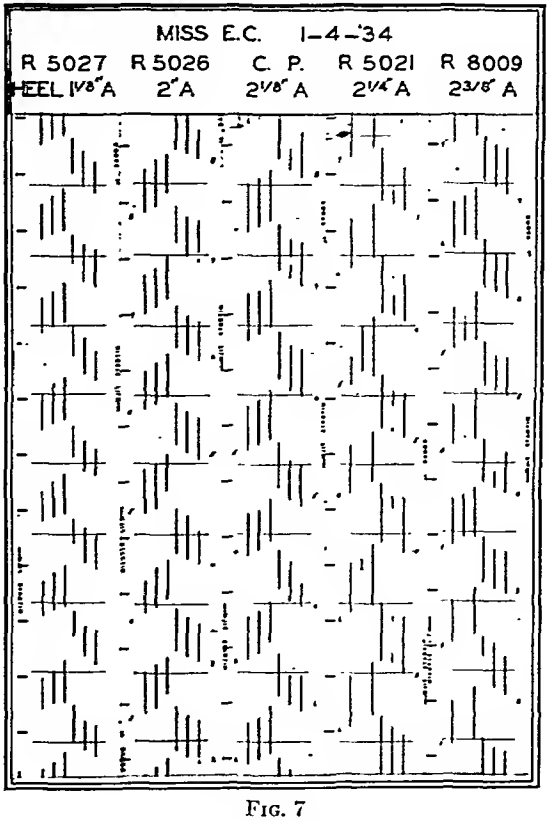

FIG. 7

Miss E. C. wore same shoes used by Miss M. S. when records in Fig. 6 were made. There was equal evidence of comfort and fit. Note prevailing instability of both feet in records R5021 and R8009.

TABLE (Fig. 7)

	Miss E. C. 1-4-'34									
Foot	R5027		R5026		C. P.		R5021		R8009	
Left heel	.60	seconds	.56	seconds	.63	seconds	.60	seconds	.65	seconds
Left 5th metatarsal	.62	"	.61	"	.63	"	.10	"	.33	"
Left great toe	.66	"	.57	"	.65	"	71	"	.73	"
Right great toe	.44	"	.61	"	59	"	72	"	62	"
Right 5th metatarsal	.52	"	.60	"	.55	"	58	"	56	"
Right heel	.48	"	54	"	.54	"	62	"	61	"
Time, left	83	"	.81	"	84	"	82	"	84	"
Time, right	77	"	.79	"	83	"	85	"	83	"

Above figures are for the average speed of 1.4 steps per second.

be free from pain, instability and abnormality in weight-bearing may result from improper design of the last with relation to the feet in question.

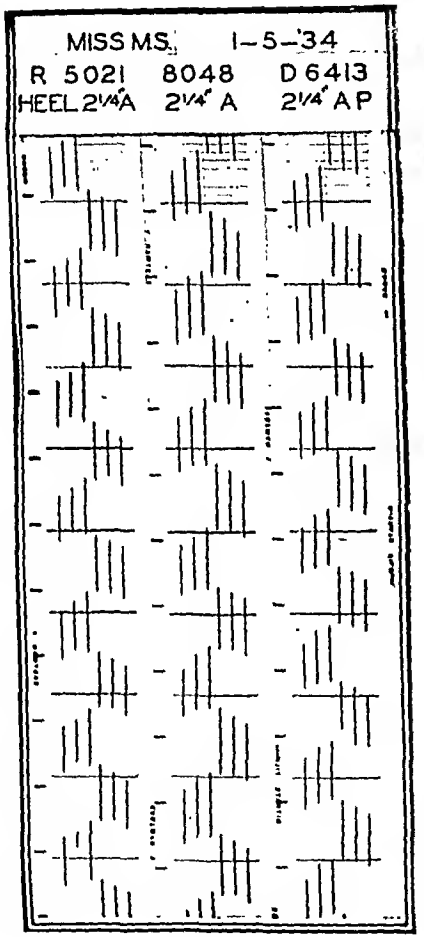

FIG. 8

Bilateral stability revealed in all three records of Miss M. S. Compare R5021 with that of Miss M. S. (Fig. 9).

TABLE (Fig. 8)

Miss M. S. 1-5-'34

Foot	R5021	R8048	D6413
Left heel	.66 seconds	.63 seconds	.63 seconds
Left 5th metatarsal	.64 "	.68 "	.69 "
Left great toe	.76 "	.75 "	.72 "
Right great toe	.74 "	.75 "	.69 "
Right 5th metatarsal	.68 "	.69 "	.71 "
Right heel	.67 "	.67 "	.68 "
Time, left	.84 "	.83 "	.82 "
Time, right	.85 "	.85 "	.84 "

Above figures are for the average speed of 1.4 steps per second.

TABLE (Fig. 9)

Miss E. C. 1-5-'34

Foot	R5021	R8048	D6413
Left heel	.60 seconds	.65 seconds	.59 seconds
Left 5th metatarsal	.10 "	.67 "	.59 "
Left great toe	.71 "	.73 "	.67 "
Right great toe	.72 "	.67 "	.63 "
Right 5th metatarsal	.58 "	.60 "	.58 "
Right heel	.62 "	.58 "	.52 "
Time, left	.82 "	.86 "	.79 "
Time, right	.85 "	.82 "	.78 "

Above figures are for the average speed of 1.4 steps per seco

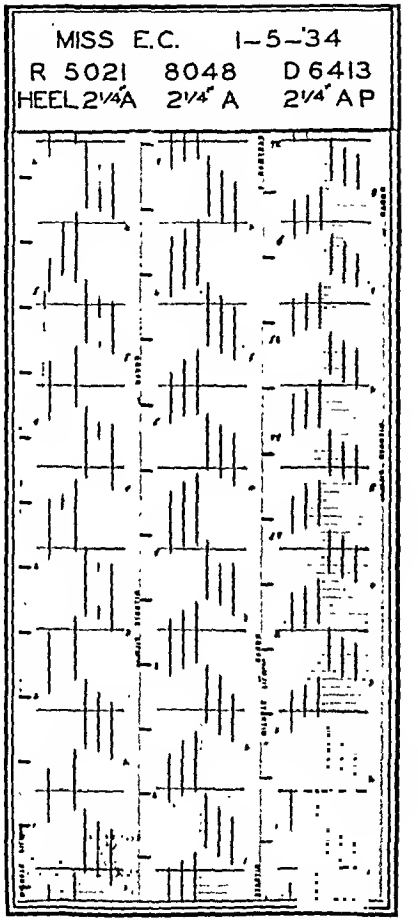

FIG. 9

D6413, personal shoes, and 8048 reveal stability of both feet in gait records. In 5021 bilateral in- with rough heel

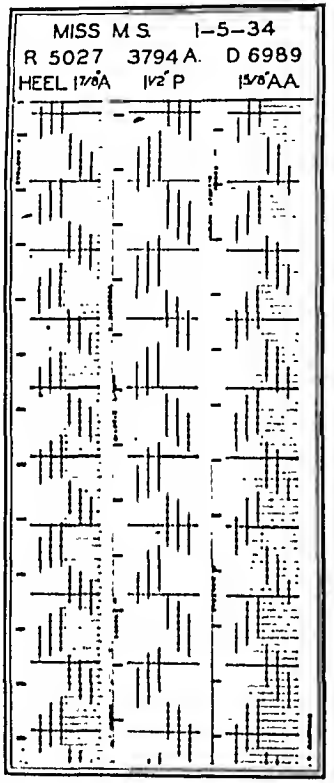

FIG. 10

Reveals short weight-bearing time on heels, particularly right for D6989. This pair of shoes was loose at the heels.

TABLE (Fig. 10)

Miss M. S. 1-5-'34

Foot	R5027	3794A	D6989
Left heel	.60 seconds	.56 seconds	.38 seconds
Left 5th metatarsal	.67 "	.72 "	.65 "
Left great toe	.70 "	.62 "	.61 "
Right great toe	.56 "	.63 "	.55 "
Right 5th metatarsal	.63 "	.69 "	.60 "
Right heel	.55 "	.51 "	.37 "
Time, left	.82 "	.85 "	.82 "
Time, right	.81 "	.82 "	.83 "

Above figures are for the average speed of 1.4 steps per second.

TABLE (Fig. 11)

Miss E. C. 1-5-'34

Foot	R5027	D6989	J6010A
Left heel	.60 seconds	.41 seconds	.63 seconds
Left 5th metatarsal	.62 "	.65 "	.63 "
Left great toe	.66 "	.51 "	.71 "
Right great toe	.44 "	.50 "	.74 "
Right 5th metatarsal	.52 "	.62 "	.65 "
Right heel	.48 "	.28 "	.59 "
Time, left	.83 "	.89 "	.83 "
Time, right	.77 "	.88 "	.85 "

Above figures are for the average speed of 1.4 steps per second.

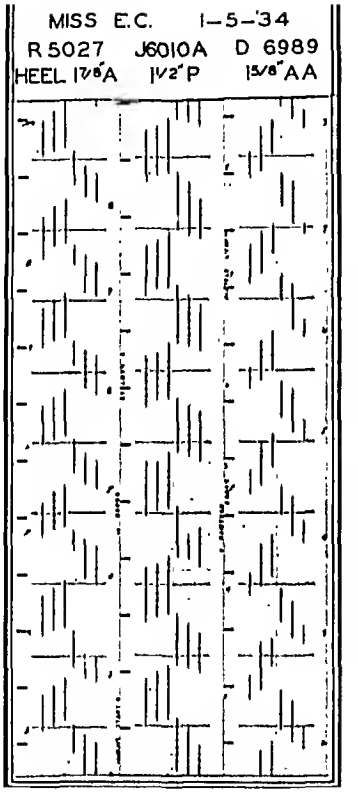

FIG. 11

Note the short duration of weight-bearing on heel and first toe in record D6989, as compared to record R5027. The 1/4 inch higher heel in the latter record should have favored the character-

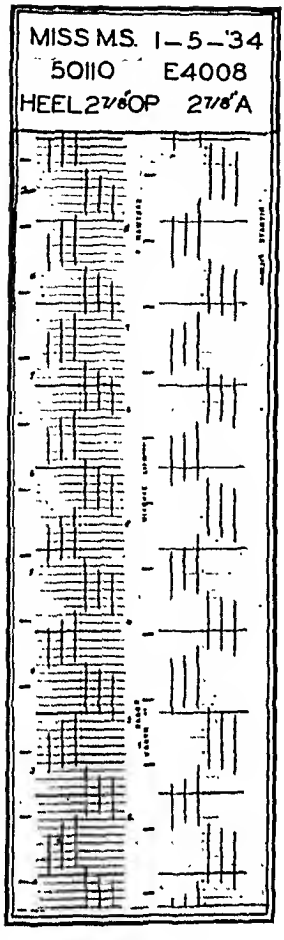

FIG. 12

Note evidence of stability in both pairs of pumps with 2⅞ inch heels worn by Miss M. S.

TABLE (Fig. 12)

Miss M. S. 1-5-'34		
Foot	E4008	50110
Left heel	.67 seconds	.60 seconds
Left 5th metatarsal	.62 "	.67 "
Left great toe	.78 "	.74 "
Right great toe	.75 "	.74 "
Right 5th metatarsal	.68 "	.62 "
Right heel	.74 "	.63 "
Time, left	.86 "	.82 "
Time, right	.85 "	.83 "

Above figures are for the average speed of 1.4 steps per second.

Since the foundation is wrong, it is useless to attempt to correct this fault by quality of material and skill in shoe construction.

Group IV included three different makes of shoes with characteristics of last design and shoe construction within the range already considered. The electrobasographic records and the slow-motion moving picture studies of this group confirmed the findings in Groups I, II, and III.

Group V consisted of two pairs of pumps with heels two and seven-eighths inches high; they were not of the same make, the heel height being the only common characteristic. They were judged to fit on the basis of contour and comfort. The electrobasographic record and the slow-motion moving picture analysis revealed marked pronation of the right foot in E4008 shoes and bilateral pronation, worse on the left than on the right, in 50110 shoes for Miss E. C. Similar records for Miss M. S. revealed a tendency toward pronation of the left foot in E4008 shoes and essentially normal stability in 50110 shoes. (See Figures 12 and 13 and the accompanying tables.)

This investigation confirms the observations made with relation to Miss E. C. (Fig. 2) and record W0063-4 (Fig. 1-A). Heel height of shoe may favor, but does not predetermine instability of the foot for a given person.

It is of importance to note that Miss E. C. revealed instability in 50 per cent. of the records, while Miss M. S. did not reveal marked instability in any. This graphic evidence suggests that a particular shoe is not equally good for all women.

CONCLUSIONS

Electrobasographic records, together with 7,000 feet of moving pictures, have been made of two women with "normal" gait, with thirteen

TABLE (Fig. 13)

Foot	Miss E. C. 1–5–'34 50110	E4008
Left heel	.50 seconds	.72 seconds
Left 5th metatarsal	.32 "	.03 "
Left great toe	.71 "	.77 "
Right great toe	.69 "	.74 "
Right 5th metatarsal	.12 "	.16 "
Right heel	.51 "	.66 "
Time, left	.82 "	.86 "
Time, right	.80 "	.85 "

Above figures are for the average speed of 1.4 steps per second.

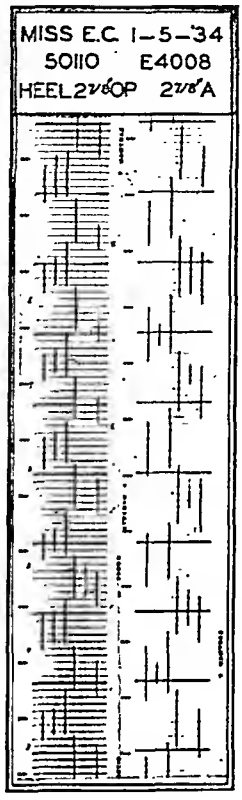

FIG. 13

Note evidence of marked instability, characteristic of bilateral pronation, in each of the above records of Miss E. C. while walking in pumps with 2⅞ inch heels.

different pairs of shoes. Interpretation of the gait records has been supported by the analysis of moving pictures made at 64 exposures per second.

The electrobasographic records have revealed the presence or absence of stability of the feet of persons wearing shoes of known last design, heel height, and quality of material, workmanship, and construction. Pronation is revealed by diminution of weight-bearing time on the fifth metatarsal head. Improper fitting of shoes, producing discomfort, is not revealed in the electrobasographic record until after the subject is unable to compensate for the pain produced.

The fitting of shoes has been based upon foot length, width, and comfort in the shoe. Little attention has been given to depth. Evidence presented indicates that stability of the foot in the shoe is not related to these criteria of fit. The shoe must, therefore, be regarded as a potential cause of inequality of weight-bearing on the three respective points of each foot.

Records indicate that shoes must differ in design of the last and other physical characteristics, so that they may fit most women with comfort and provide stability for the feet under the influence of weight-bearing. Although new shoes of inferior quality of material and workmanship may be comfortable and provide stability, they are more predisposed to the loss of the latter essential characteristic with increasing use and poor care.

Evidence indicates that, although the size of shoe may be correct and the foot may be free from pain, instability and abnormality in weight-bearing may result from improper design of the last with relation to the feet in question. This fault cannot be corrected by quality of material and skill in shoe construction. The foundation is wrong.

Data justify the statement that even a heel two and seven-eighths inches high may be worn upon occasion without subjective discomfort or

recordable indication of instability of the feet. Some feet are more unstable than others; therefore, a particular shoe may not provide equal stability for different individuals.

The final conclusion of this work is that all of the factors pertaining to the relation of the patient's shoes to electrobasographic records are under control.

ACKNOWLEDGMENT

It is always a pleasure to reveal the names of those to whom one is indebted for assistance in his work. The number is large and, therefore, prevents mention of those whose moral support has been so helpful in bridging many gullies caused by washouts of disappointments.

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An Eastman Ciné Kodak Special was used in this work.

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THE SOURCE OF PAIN IN AMPUTATION STUMPS IN RELATION TO THE RATIONAL TREATMENT

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The problem of pain in amputation stumps may still be regarded as unsolved. Among the existing theories concerning the origin of such pain, the least stable are the two which more than any others influence the modern treatment: (1) the theory of amputation neuromata, produced in such principal nerve cables as the sciatic in the lower limb and the ulnar and radial in the upper limb; (2) the theory of ascending neuritis, advanced by Weir Mitchell. A consideration of the following well known physiological and anatomical facts may help to bring about a clearer understanding of the subject.

Electric or mechanical irritation of different nerves produced on the operating table has confirmed the existence in some of the peripheral nerve fibers of special pain conductors, in addition to the branches which convey tactile temperature and other forms of skin sensibility. These pain conductors are contained principally in the cutaneous nerves, with definite territories supplied by separate branches. This fact must be taken as a starting point in the search for the cause of pain in amputation stumps, which has baffled all attempts at treatment.

Taking into consideration the effect of mechanical and electric irritation of nerve trunks, it has been found of equal value to examine systematically the skin scar in each case of painful amputation stump. From these examinations of the locally painful scars, the following peculiarities have been found.

If the scar is irritated, projected pain can be evoked, the character and peripheral distribution of which are identical with those of the pain felt by the patient in the amputated limb. Irritation of strictly localized points on the scar produces pain shooting toward definite areas of the "phantom limb". The direction of this pain, whatever territory it may involve, very often corresponds to that of the spontaneous pain and to the anatomical course of the pain conductors revealed by the production of electric irritation in the investigations carried out. Evidence of the existence of such pain, originating in the skin scar independently of that arising from amputation neuromata of larger nerves, may be obtained by consideration of the three following facts.

In accordance with the modern technique of amputation, the neuroma is found to be situated at a distance from the skin scar, with no adhesion to the plane of section of the bone. The second proof is provided by the fact that, in examining the skin scar as the source of projected pain

evoked by the pressure, percussion, or even the touch of a camel's hair brush, it is possible in some cases to reproduce definite isolated irritation of the different points by lifting a fold of the scar or drawing it from the underlying structures. The third support of this assumption is founded on the fact that the comparison of the distribution and character of the projected pain evoked from the neuroma or from the skin scar generally reveals no agreement. The pain arising from the scar differs as a rule from that connected with the neuroma and is more severe.

Taking these facts as a guide in the treatment of pain in amputation stumps, it has been possible to deduce the following conclusions, based on eleven clinical cases in which section of the cutaneous nerves exclusively was undertaken.

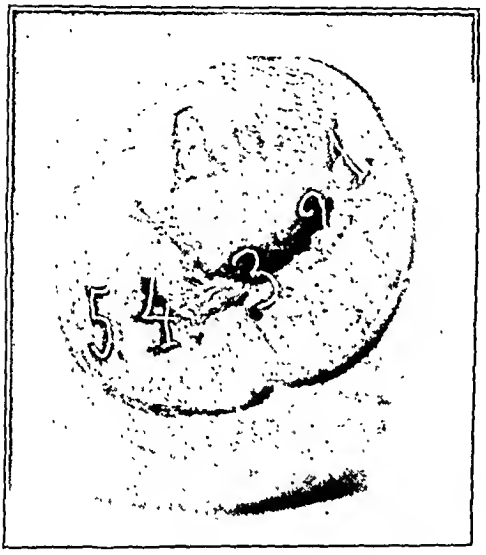

FIG. 1

Painful stump after amputation of the leg. The numbers indicate the points from which pain is projected to the corresponding toes on pressure, touch, or the prick of a pin. These sensations disappeared in the first three toes after division of the obturator and in the fourth and fifth toes after division of the cutaneous femoris lateralis.

Amputation pain has no causal relation to the neuromata of large nerve trunks or to any abnormal state of bone, muscular, subcutaneous, or vascular tissue. Its origin may be traced to the involvement of terminal ramifications of cutaneous nerves which conduct the special sense of pain. Since these nerve branches are necessarily divided during amputation, they are inevitably included in the scar.* The facts cannot be ignored that these external agents which affect the ramification of cutaneous nerves are not to be regarded as the sole element in pain production and that the section of cutaneous nerves impairs the compensatory and antagonistic relations between two systems of fibers,—those of special sensibility to pain and those of other forms of sensibility, principally tactile and thermic, the existence of which has been proved by Head in experiments performed upon himself.

Leaving aside such complications as trophic and vasomotor disturbances, amputation stumps may be divided into two groups which differ distinctly in their clinical manifestations of pain. The first and most interesting group is distinguished by predominating pain projected toward

* Krunkenberg's operation for obtaining a prehensile forearm after amputation leads to the formation of a complicated long stripe of skin scar which is a source of grave intractable pain. Two such cases have been observed in which a series of operations—including section of the principal nerves, rhizotomy, and spinal ganglionectomy—failed to alleviate the pain. Section of the cutaneous antibrachii lateralis and cutaneous antibrachii dorsalis resulted in abolishing the suffering of the patients.

the non-existent limb. The pain is localized exclusively in the terminal parts, such as the hand, foot, fingers, and toes, and is accompanied by different illusory disturbances of motion. Local pain is not complained of in these cases. In contrast to this group, the second group is characterized by predominating purely local pain which, on closer examination, is found to arise from the scar. No irradiating toward the periphery of the "phantom limb" is observed in these cases.

In the treatment of pain projected toward the inner malleolus, the medial side of the foot and sole, and principally toward the big toe or

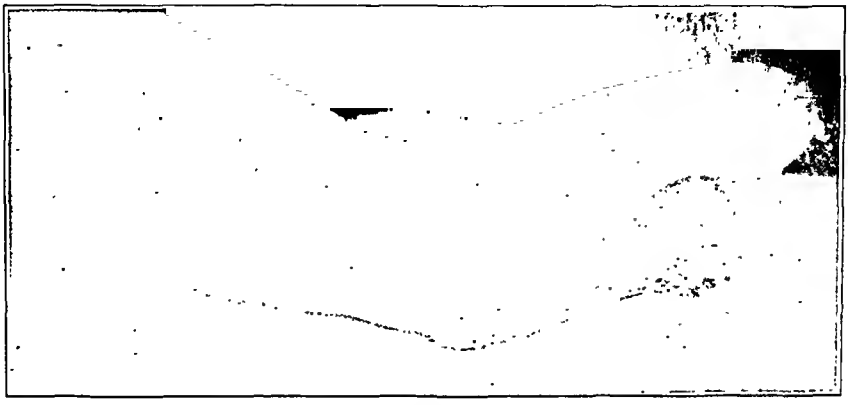

FIG. 2

Krunkenberg's "claw", with sensation projected into the thumb and index finger in the form of burning and in the dorsum of the hand in the form of frost. The burning sensation disappeared after division of the cutaneous antibrachii lateralis and the frost after division of the cutaneous antibrachii dorsalis.

partly toward the other toes (with the exception of the fifth), in cases associated with tenderness of the medial part of the scar presented by a thigh or leg stump, experience has shown the efficaciousness of division of the obturator near its exit from the foramen obturatum. Other ways of approaching this nerve are certainly admissible.

In cases of pain projected toward the external malleolus, the outer side of the dorsum of the foot, the little toe or the adjacent part of the sole, with coexisting local tenderness of the outer part of the scar, not inferior results were obtained from section of the cutaneous femoris lateralis just below the anterosuperior iliac spine. An additional section of the lumboinguinal nerve, below Poupart's ligament, was found useful in cases of pain irradiating toward the anterior part of the thigh and knee in which tenderness was revealed in corresponding points in the scar.

In painful stumps of the upper extremities, with pain localized in the first three fingers and in the corresponding volar surfaces of the hands, section of the cutaneous antibrachii lateralis was successful.

It must be emphasized that the operations proposed are of little or no avail in cases of high amputation of the upper or lower limbs. Experience leads one to assume that, at the level of the middle third of the thigh and

the upper third of the forearm, one has to deal with other conductors of pain as yet not recognized.

It is to be noted that the rôle of cutaneous nerves as conductors of pain originating in scars is being more and more recognized. As far back as 1856, Pirogoff reported two cases of neuralgia of the arm, which were successfully treated by section of the cutaneous filaments of the nerve which had been involved in a scar resulting from venesection. In the writings of recent authors which deal with the subject of pain in amputation stumps, significance is attributed to cutaneous nerves.

Elmslie states that, in cases in which pain continues to exist after section of the ischiatic nerve, division of the saphenous nerve may be resorted to.

Foerster, in 1927, in referring to treatment of painful-stump neuromata, recommended blocking, as high as possible, of all the peripheral nerves by alcohol or formalin. In severe painful cases, not one of the nerves should be omitted from this treatment in order that absolute insensibility of the stumps may be obtained.

Küttner, in dealing with the same subject at the German Congress of Surgeons in 1931, recommended lines of treatment similar to those of Foerster. His opinion is that "although in some cases neuromata of small nerve branches cannot be eliminated, it is sometimes not easy and even impossible to discover them; therefore we obtain success by the high blocking of a denuded main trunk".

Some considerations of the source of stump pain are to be found in the writings of Leriche (1932). He reminds the reader that "there are in the thigh other nerves beside the ischiatic" and reports a case of neuroma of the saphenous nerve to the existence of which pain in the stump could be traced. In addition, he points to one case in which resection of fifteen centimeters of this nerve had no effect in abolishing the pain. As to the upper extremity, Leriche takes absolutely no account of cutaneous nerves in the causation of pain following amputation. He speaks of three main nerve trunks and, according to his experience, it may be necessary to divide all three, not limiting the operative interference to one of them. The significant rôle of the scar and of the definite cutaneous nerves involved therein is not stressed by him.

In regard to the method of treatment of pain in amputation stumps which is advocated in this paper, the author must acknowledge that his experience is not large enough to draw broad conclusions, but, taking into consideration the severity of the suffering with which one so frequently has to deal and the futility of the many grave operations which have been resorted to in the attempt to abolish intractable pain in the stump, he dares to recommend a trial of operative methods which are far less radical in comparison to those hitherto practised.

In the combat with stump neuralgia, the summit of radicalism has been reached in the operation of rhizotomy which tends to sever the roots of the channels conducting pain from a distant undetermined source.

According to Shaw, "in cases of stump neuralgia of the upper and lower limbs, all ventral and dorsal roots should be severed". The frequent failure of this procedure to abolish pain is well known; the same may be said of sympathectomy and ganglionectomy. Because of these facts, Leriche is inclined to question whether, in some particular cases of rebellious pain following amputation, excision of the sensible centers of the cortex may be resorted to. This state of affairs has led the author to suggest a new line of treatment based on a more profound study of the pathways of pain in amputation stumps and the determination of the local source of irritation.

SUMMARY

Neuromata of large nerves play a secondary rôle in the production of pain in amputation stumps.

The source of the pain is to be sought in the stump scar in which are involved the endings of the pain-conducting finer branches of the cutaneous nerves. The determination of the special cutaneous nerve to which the sensitive filament belongs must be the starting point in treating the pain. This task is not always easy. A better knowledge of the anatomy and physiology of the cutaneous nervous system will serve to overcome existing difficulties.

A higher section of the real conductor of pain originating in the stump scar is apt to interrupt pain which may have repeatedly baffled other operative methods.

A new vista is being opened for the treatment of pain in amputation stumps, based on a more thorough study of special pain-conducting nerves which have nothing in common with the nerves carrying other forms of sensibility.

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AN OPERATION FOR THE CORRECTION OF PRONATED FEET

BY RICHMOND STEPHENS, M.D., NEW YORK, N. Y.

The results of treatment in many cases of weak foot, either relaxed or rigid, have not been thoroughly satisfactory. Various operative procedures have been tried in severe cases, but, up to the present time, none has been found that is always successful.

Shortly after a visit to Dr. Michael Hoke, of Atlanta, Georgia, during which the author saw a great deal of his work on foot deformities, the following operation was evolved by modifying and adding to Dr. Hoke's operation for valgus feet.

THE OPERATION

A curved incision, such as might be employed for an astragalectomy or a subastragalar arthrodesis, is made on the outer side of the foot below the fibular malleolus. The peroneal tendons are exposed and retracted and the head of the astragalus is exposed. An osteotomy through the neck of the astragalus is then done with a chisel and the head is removed. In rigidly pronated feet it is found that the deformity can then be well corrected without the use of force. The articulation between the astragalus and the os calcis is next exposed, the cartilage of both bones is denuded, and the joint space is increased by inverting the heel, thus leaving a gap between the two raw-bone surfaces. The head of the astragalus which was removed is denuded of all cartilage and ligamentous attachments and is cut in the form of a wedge. This bone wedge is then inserted in the space between the body of the astragalus and the os calcis, with its base to the outer side of the foot. The thickness of the wedge depends on the amount of correction desired. The wound is then closed and plaster is applied from the tips of the toes to the upper end of the calf. While the plaster is being applied the foot is held at a right angle with the correction at the scaphoid region, the head of the first metatarsal is held down, and the heel is in inversion.

At the end of three weeks the plaster is removed, the wound inspected, and a new plaster applied for five weeks, making the total period of immobilization eight weeks. After this period, the patient should use the foot with an ordinary unaltered shoe. In some cases it may be necessary to raise the inner border of the heel or even to supply some sort of a support for a few months. Massage and exercises may be helpful in some cases. It is true that the motion in the subastragalar joint has been sacrificed, but it is the author's belief that the benefits obtained in cases of severely pronated feet more than make up for this loss.

DISCUSSION OF CASES

In the cases reported, the patients were operated upon in 1929 and, since five years have elapsed, it is felt that the benefits obtained from the

operation can be fairly judged. This series of cases comprises: two boys with bilateral relaxed flat-foot; one girl with bilateral rigid flat-foot; and one boy with unilateral traumatic rigid flat-foot. In three of the cases both feet were operated upon, making a total of seven operations. These patients were all children, but the author believes that the procedure would be just as beneficial if used in the case of a young adult. The operation is also recommended in cases of relaxed or rigid feet.

The x-rays before operation were all negative for accessory scaphoids and merely showed the depressed arches. Unfortunately, there are no photographs and in only one case were plaster models of the feet made before and after operation. Two of the patients moved away after a few months and have not been available for late examination, but the other two are still under observation and the results in each case are thoroughly satisfactory.

CASE REPORTS

CASE 1. N. R., a female, eleven and a half years of age, considerably overweight, suffered from pain and stiffness of both feet.

The patient had been treated with Whitman plates and altered shoes for two years. On July 26, 1928, both feet had been manipulated under anaesthesia and had been immobilized in plaster. The x-rays showed large depressed scaphoids, but no accessory scaphoids. After three weeks the plaster was removed, physiotherapy was instituted, and braces and altered shoes were again used. She was temporarily improved, but later the disability recurred.

A year later the patient was readmitted; the feet were painful, tender, rigid, and pronated with prominence in the scaphoid regions. The operation described was done on the right foot on July 6, 1929, and on the left on July 11, 1929. In the case of the right foot, the wedge was made up of two pieces of bone instead of a single piece. The plaster was finally removed on August 28, 1929. Each foot showed less scaphoid prominence and moderate inversion of the os calcis. Because of the extreme pes planus, the patient was given shoes raised one-eighth of an inch on the inner borders of the soles and one-quarter of an inch on the inner borders of the heels.

This girl has been followed at intervals up to the present time. She is thoroughly satisfied with the results of the operations and, although the feet are still somewhat flat, she gets along without supports and with unaltered shoes. She does tire somewhat after long walks or periods of standing.

CASE 2. J. B., a male, eight years of age, was admitted to the Hospital on July 23, 1929, because of the condition of the feet.

For two years he had attended the Out-Patient Department and had used Whitman braces with no relief. X-rays were negative for accessory scaphoids.

On admission, the feet were completely relaxed and everted, with the long arches down and the scaphoid regions prominent.

An operation was performed on the left foot on July 25 and on the right foot on August 1. Both feet were immobilized in plaster until September 18. The feet then showed marked inversion of the heels. Unaltered shoes were ordered, but it was later found that the patient had used his old shoes with the inner borders raised.

After three months the condition of the left foot was satisfactory, but the right foot showed too much inversion of the heel. This condition continued to increase and, on July 10, 1930, the patient was again operated upon. It was found that where the piece of the astragalus had been inserted there was marked overgrowth of bone pushing up against the fibular malleolus and causing the inversion. This excess bone was removed and also an external longitudinal wedge. At the same time the left foot was stretched and put in

plaster as it showed slight overcorrection. A photograph, taken November 28, 1930, showed the feet in good position.

On October 25, 1934, the patient was found to be thoroughly satisfied. He walked well and had no discomfort. Each foot appeared excellent with a moderately long arch and the os calcis in slight varus.

From this case we learned that it was possible to get too much correction and this had to be remedied a year later. The wedge was probably too thick and there was also an overgrowth of bone. Up to this time the author thought it more likely that there would be a thinning with too little correction rather than a gradual increase with growth.

CASE 3. R. S., a male, thirteen years old, was admitted to the Hospital on July 30, 1929, complaining of pain and stiffness and showing eversion of the left foot, a prominent scaphoid, marked tenderness, spasm and rigidity.

The patient gave a history of a fall on December 31, 1928, with probable strain of the left foot.

The regular operation was done on August 1, 1929, and the foot was immobilized in plaster for eight weeks. The foot was then relaxed and the heel inverted. The patient went without support, but the inner border of the heel was raised one-eighth of an inch.

This patient was only followed a short time, but, on December 11, 1929, his foot appeared to be in excellent position, he walked well, although he held the ankle somewhat stiffly, had no discomfort, and seemed well satisfied.

CASE 4. R. M., a male eleven years old, had used Whitman braces for two years without improvement.

On admission to the Hospital, the long arches were depressed and there was marked prominence of the scaphoid region. X-rays did not show the presence of accessory bones.

Typical operations were performed; the left foot was operated upon on November 21, 1929, and the right foot on November 30, 1929.

On January 24, 1930, the plaster was removed and the feet were found to be in good position with the os calcis of each foot in slight inversion. Unaltered shoes were used.

This patient could only be followed for a short time, but, on April 30, 1930, plaster casts were made to compare with those made just before the operations. The appearance of the feet was good, that of the right being slightly better than that of the left. The boy was very well pleased with the condition of his feet and did not tire.

SUMMARY

1. Some weak feet do not respond to the ordinary conservative treatment and operation is indicated.
2. Many operations have been done which have resulted in definite improvement, but none of these operations has been outstandingly successful.
3. The operation described here is moderately simple, can be used for all types of weak or flat feet, and is applicable to adults as well as children.
4. The results obtained through the use of this operation are satisfactory cosmetically as well as functionally.
5. The use of appliances and special shoes may usually be discontinued after the operation.
6. There is some danger of overcorrection in growing children, as illustrated in one case.

COMBINED ANTERIOR-POSTERIOR APPROACH TO THE KNEE JOINT

BY EDWIN FRENCH CAVE, M.D., BOSTON, MASSACHUSETTS

From the Massachusetts General Hospital

The incision for exposing the semilunar cartilage, about to be described, allows access to the anterior and posterior compartments of the knee joint with a minimum amount of trauma to the articular surfaces. It has been particularly useful in removing cysts of the semilunar cartilage, cartilage with damage to the posterior cornu, and any injured cartilage which it is difficult to remove by means of the restricted anterior approaches.

The knee is flexed at a right angle over the end of the operating table. To expose the internal semilunar cartilage, the internal epicondyle of the femur is identified, and the incision begun three-eighths of an inch behind and on a level with this point,—about one and one-half inches above the joint line. Posterior to this bony landmark pass the tendons of the sartorius, gracilis, and inner hamstring muscles which have their insertion in the upper end of the tibia. The incision is carried downward and curved gradually anteriorly to a point one-quarter of an inch below the joint line, and then forward to the border of the patellar tendon (Fig. 1-A). The skin flap, with subcutaneous tissue and fat, is reflected upward to expose the quadriceps expansion and the lateral ligament. The first, or anterior, incision into the joint capsule begins just in front of the lateral ligament as it takes its origin from the internal femoral condyle (Fig. 1-B). The incision is carried downward and forward to just below the joint line, and further forward to the patellar tendon with the same general curve as the skin incision. The synovia is opened through this same incision, and the anterior cornu of the internal semilunar cartilage is exposed (Fig. 1-C). At this point, it is well to insert special retractors to allow exploration of the anteromesial compartment of the joint (Fig. 2).

The following structures can be viewed satisfactorily through this incision: the articular cartilage of the internal tibial and femoral condyles, the anterior crucial and alar ligaments, the inferior surface of the patella, the fat pad, the synovial lining, and the anterior half of the internal semilunar cartilage. A satisfactory view of the external semilunar cartilage cannot be gained from the anteromesial approach.

By sharp dissection, the anterior portion of the cartilage is freed from its attachment to the synovia and the fibrous ligament by which it is attached to the anterior crucial ligament (Fig. 1-D). Once the anterior portion of the cartilage is free, it may be grasped firmly with a Kocher clamp and pulled forward as it is dissected from its attachment to the internal lateral ligament.

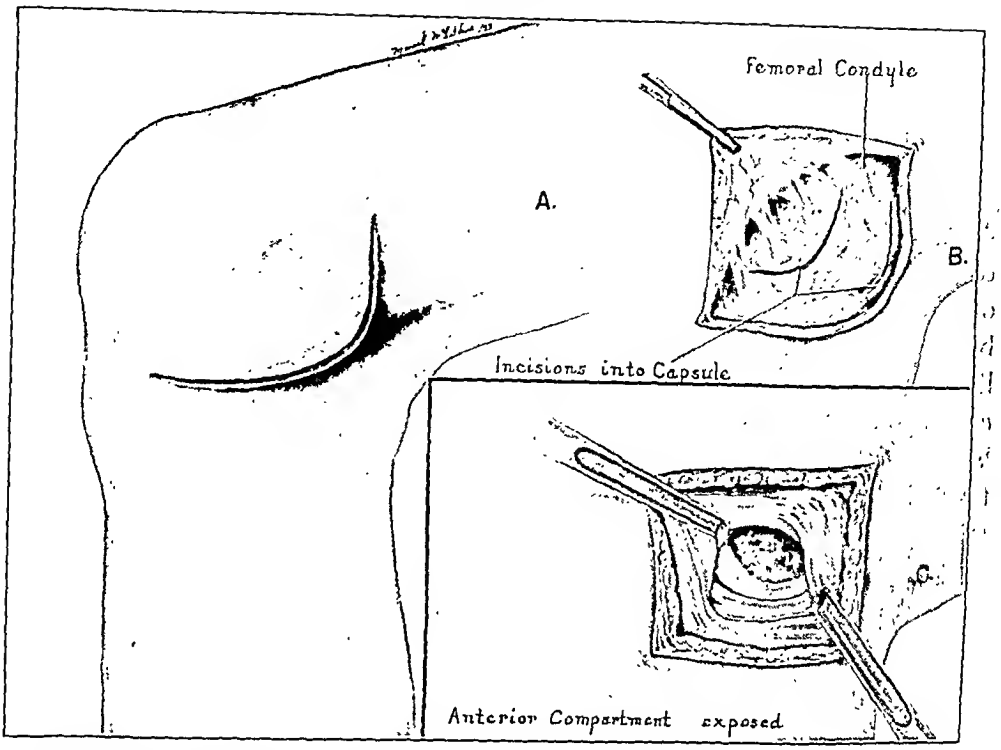

FIG. 1-A. *Skin incision, beginning about three-eighths of an inch back of the femoral epicondyle and extending downward and forward to the patellar tendon.*

FIG. 1-B. Incisions into capsule. The anterior incision begins just in front of, and slightly below, the femoral epicondyle and extends downward and forward to the patellar tendon. The posterior incision is made in line with the ligamentous fibers of the capsule.

FIG. 1-C. The anterior opening into the joint, showing the semilunar cartilage *in situ*.

If removal of the posterior portion of the cartilage proves difficult, if a lesion of the posterior portion of the cartilage is suspected, or if one is dealing with a cyst of the cartilage, it is a simple matter to open the knee joint behind the internal lateral ligament. This second incision is made behind the internal lateral ligament, beginning just below the level of the epicondyle of the femur and continuing straight down across the joint line (Fig. 1-B). The capsule and synovia are more easily opened separately than by one incision. Posteriorly, the tibial and femoral condyles are in close contact with the semilunar cartilage lying between them (Fig. 1-E). With this postero-mesial approach, however, the semilunar cartilage should be separated from its attachment

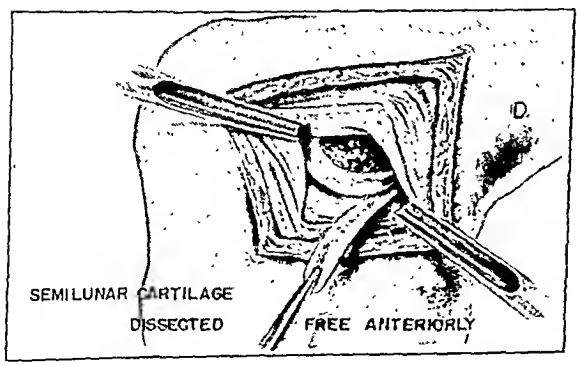

FIG. 1-D

The anterior portion of the semilunar cartilage dissected free and brought out through the anterior incision.

to the synovia by sharp dissection; essentially all of the cartilage can be removed by this means once the anterior half has been dissected free. At times it has been helpful to pass the freed anterior end of the cartilage posteriorly between the internal lateral ligament and the femoral condyle, and the entire cartilage can be removed through the posterior opening into the joint.

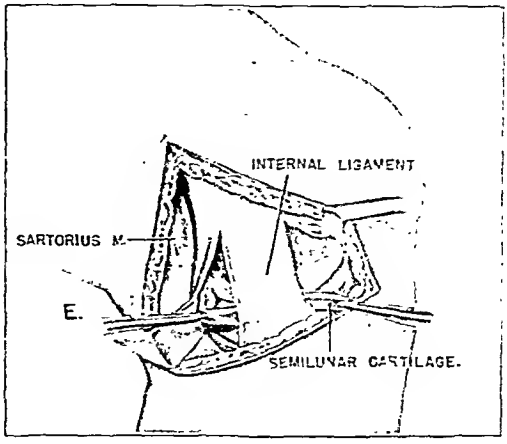

FIG. 1-E

The mesial side of the knee joint, showing the capsule opened in front of, and behind, the internal lateral ligament and the cartilage dissected free except for its extreme posterior attachment.

In exposing the lateral aspect of the joint, the skin incision is made exactly the same as the one described,—beginning three-eighths of an inch behind and on a level with the external femoral condyle, and curving downward and forward to the patellar tendon. The incision for exposing the anterior compartment is also made in a manner similar to the incision used on the mesial side. It will be found, however, that, when the knee is flexed, the anterior cornu of the external semilunar cartilage has a great tendency to retract, and it may be exposed and dissected free with some difficulty. Once the anterior cornu is freed, however, traction with a Kocher clamp will draw the cartilage easily forward since it is not firmly attached to the external lateral ligament. The popliteus tendon, which lies mesial to the external lateral ligament, arises from the external femoral epicondyle and passes downward and posteromesially. It is separated from the external semilunar cartilage by a small bursa. If, when removing a cartilage with cystic degeneration or dealing with an injury to the posterior cornu of the cartilage, it is necessary to make a second incision into the joint to free the posterior cornu of the cartilage, the incision is made just behind, and in line with, the fibers of the external lateral ligament (Fig. 1-F). As the capsule of the joint is opened, the

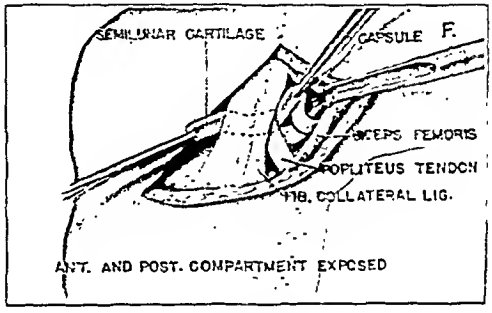

FIG. 1-F

The lateral side of the knee joint, showing the capsule opened in front of, and behind, the fibular collateral ligament and the semilunar cartilage dissected free except at the extreme posterior tip. The other structures seen are the popliteus tendon and the tendon of the biceps femoris.

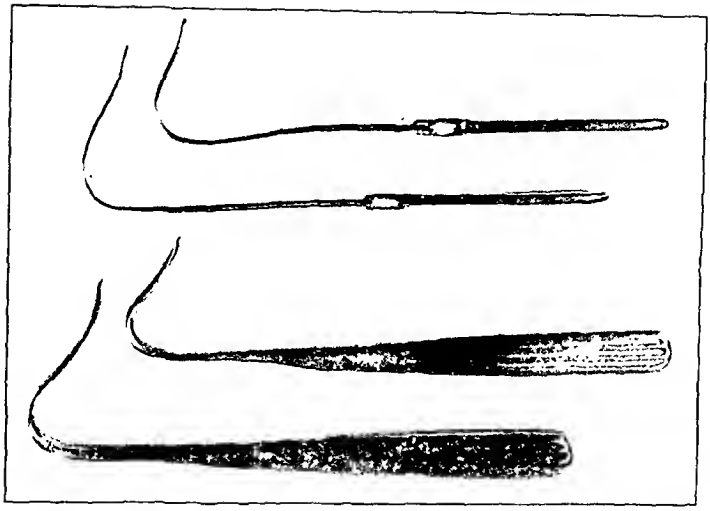

FIG. 2

Retractors varying from one-quarter of an inch to three-quarters of an inch in width and shaped so as to conform to the curve of the joint line.

popliteus tendon comes into view just anterior to the incision, and the lateral head of the biceps tendon lies posteriorly. The lateral condyles of the femur and tibia are in less close apposition than on the mesial side, with the semilunar cartilage lying between the two. The posterior cornu of the cartilage can be removed by sharp dissection. It may facilitate matters to pass the anterior portion of the cartilage posteriorly, mesial to the external lateral ligament and the popliteus tendon, and remove the entire cartilage through the posterior opening.

The incisions into the joint are closed separately in two layers. The subcutaneous tissue and skin are closed separately. Silk is used throughout.

Sixteen cases have been operated upon using the incision described. There were ten injuries to the semilunar cartilages, four cysts of the external semilunar cartilage, one cyst of the internal semilunar cartilage, and one cyst within the internal lateral ligament.

COMMINUTED FRACTURES OF THE PATELLA

Treatment of Cases Presenting One Large Fragment and Several Small Fragments*

BY J. E. M. THOMSON, A.B., M.D., F.A.C.S., LINCOLN, NEBRASKA

Fractures of the patella were among the first fractures to be brought within the scope of open operative procedures, yet they still offer problems and complicating sequelae that often prove distressing to the surgeon and to the patient. The controversy among authorities as to which procedure is appropriate has, however, been reduced to the quite general agreement that open operation is always in order, providing the fragments are widely separated and the patient is a good risk.

The procedure here described is limited in its adaptability to those transverse and comminuted fractures in which there is one large fragment intact in the upper or lower portion of the patellar tendon.

This type of fracture is quite common and frequently occurs as the result of an automobile accident in which the patient has been thrown with the knees against the instrument panel or some other forward obstruction in the car.

PREOPERATIVE TREATMENT

Three to seven days should elapse after the injury before operation is considered, during which period an effort should be made to aid absorption and diminish swelling. The extremity should be wrapped with a bias cotton-flannel bandage. Traction or splints should be applied, with the extremity fully extended and maintained in an elevated position in bed. It would be helpful if ice-bags were to be applied to the knee for interrupted periods.

OPERATIVE TECHNIQUE

When conditions seem favorable, operation is performed under appropriate anaesthesia (local, spinal, or general). Meticulous surgical preparation is essential, and the hemorrhage is controlled by means of a tourniquet about the mid-thigh. A generous longitudinal semilunar incision is made laterally away from the patella. The small fragment, or fragments, is cut freely from the tendon, rather than being bluntly dissected or torn out, to assure removal of all bony particles. Blood clots are removed. The rough edges of the remaining large fragment are smoothed and contoured, particularly on the articular surface; shredded, stringy bits of loose tendon are cut away. Two drill holes are made obliquely from the upper surface of the fragment to the lower portion of the fracture surface, but well anterior to the articulating cartilage. A strong kangaroo tendon is passed through one of these holes, interwoven

*Read before the Section on Orthopaedic Surgery of the American Medical Association, Cleveland, Ohio, June 13, 1934.

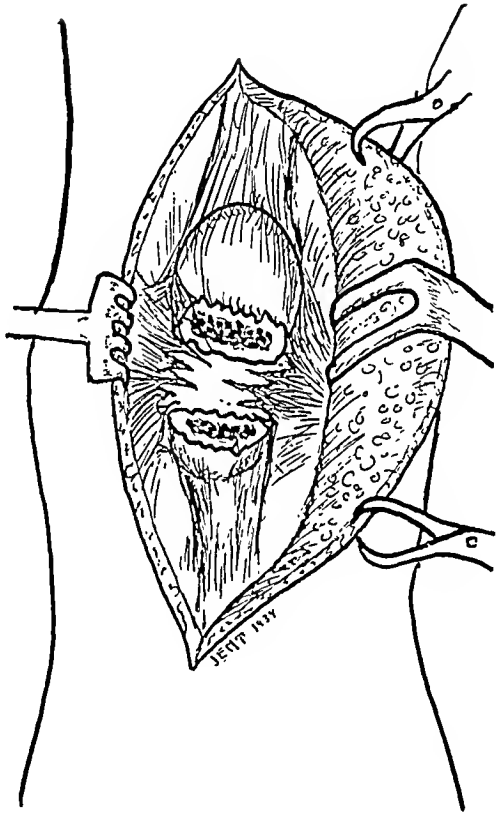

FIG. 1

Fracture of lower portion of patella, with separation of fragments and shredding of tendon fibers between fragments. Longitudinal semilunar incision. Skin flap reflected. Patellar region exposed.

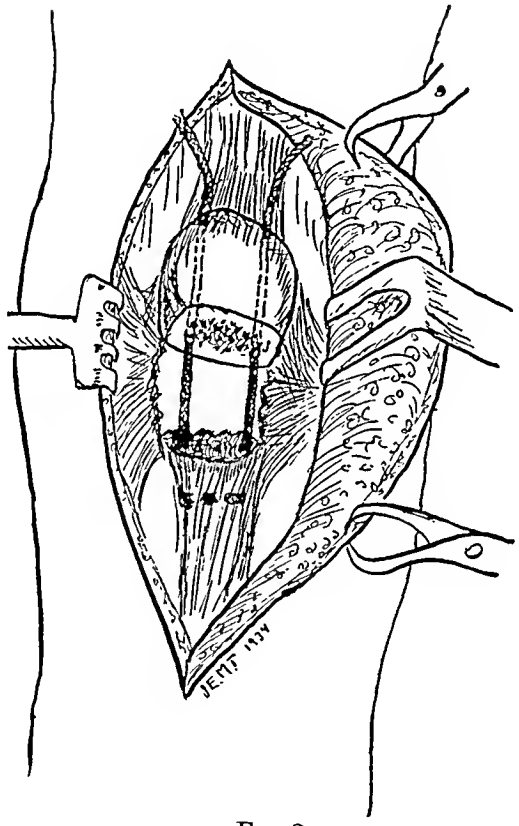

FIG. 2

Small lower fragment removed. Shredded tendon fibers cut off. Edges of fractured patella smoothed. Drill holes identified as they pass through substance of patella with kangaroo tendon suture in place.

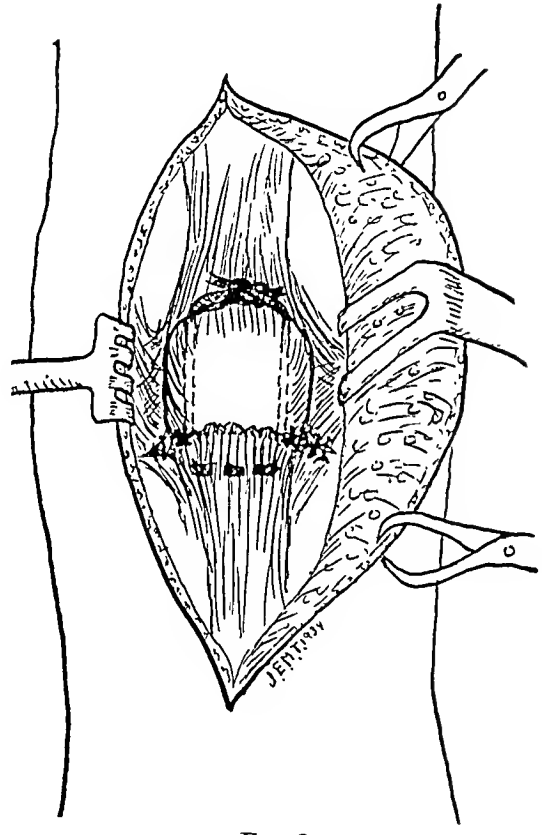

FIG. 3

Lower patellar tendon drawn snugly against patellar fragment and kangaroo suture tied securely. Capsule and tendon structure closed.

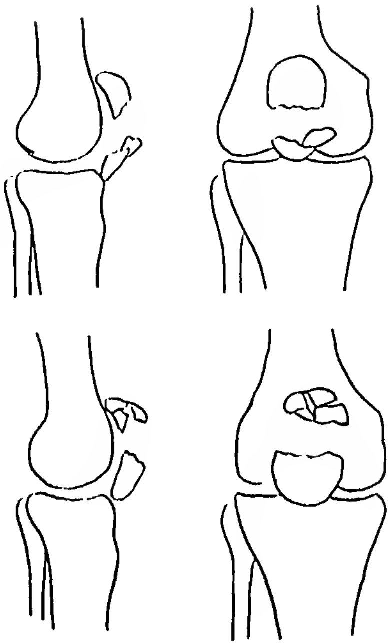

Fig. 4

Tracings from x-rays of fractures of lower and upper portions of patella, showing smaller fragments which are suitable for removal.

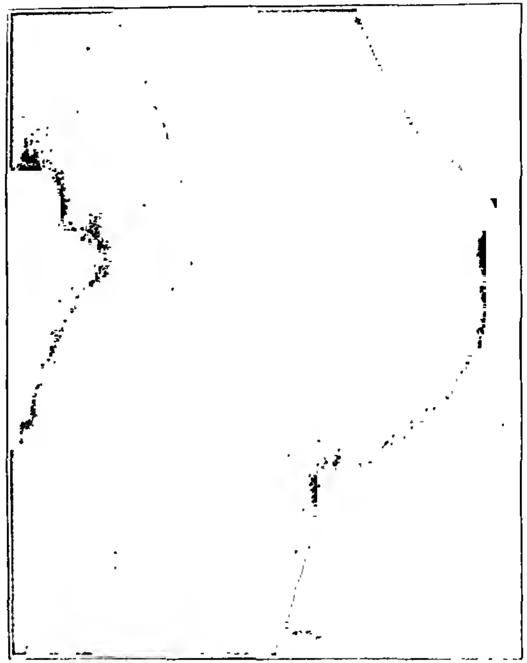

Fig. 5

Severe comminution of lower portion of patella, due to direct violence. Operation consisted of removal of fragments and union of tendon to large remaining fragment. X-ray taken before operation.

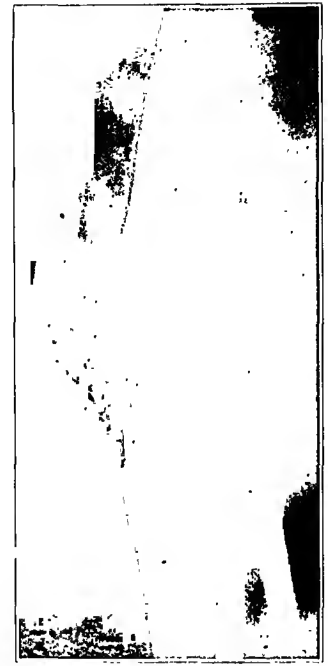

Fig. 6

Same case as in Fig. 5. X-ray taken fourteen weeks after operation, showing smooth, normally placed patella with perfect function to the extremity.

deeply into the substance of the opposing patellar tendon, and looped back through the other drill hole. Fascia may be substituted for this purpose. The fragment of the tendon is then approximated firmly against the patella and the kangaroo strands tied across the fragment of the patella. Chromic catgut approximation of lateral torn tendinous and capsular attachments should be carefully carried out. The wound is closed with Dermal or silk, and sterile dressings, moistened with alcohol, are applied. Sheet wadding is wrapped from the mid-calf to the mid-thigh, and a cotton-flannel bias bandage is applied from the toes to the upper thigh. The tourniquet is then removed. Leaving the tourniquet intact until after bandaging seems to reduce postoperative intra-articular hemorrhage. Either a molded posterior plaster splint from the toes to the upper thigh, or a double lateral iron splint, is applied. Ice-bags are reapplied to the knee, and the leg is elevated.

At the end of seven to ten days the stitches are removed. A strong dressing of Unna's paste is applied to the extremity, thereby allowing only limited flexion of the knee, and the patient is then allowed to walk with crutches. Three weeks after operation full weight-bearing is allowed, and motion is limited only by the cotton-flannel bias bandage. Physiotherapy is seldom required to bring back function.

The result obtained by the use of this procedure has, in the author's small series of five cases, proved in every instance uniformly satisfactory.

CONCLUSIONS

This procedure reduces the problem of the treatment of certain fractures of the patella from one in which there is an effort to attain bony or fibrous union of fragments that normally exhibit very little osteogenic resourcefulness, to one in which only union of tendinous structures is involved, and in which there is assurance of success if meticulous asepsis is observed and adequate sustaining suture of soft structures is carried out. Such a procedure allows early use of the extremity, decreases the period of disability, and relieves much of the possibility of refracture.

THE USE OF THE JONES SPLINT IN THE TREATMENT OF FRACTURE OF THE PELVIS AND OF THE NECK OF THE FEMUR

A Series of Forty Cases

BY A. J. LANGAN, M.D., F.A.C.S., SAN PEDRO, CALIFORNIA

Fractures about the pelvis and neck of the femur have always been a source of worry to the surgeon. Fractures of this kind are most common in the poorer type of surgical risk,—namely, old people. Among the various measures in the treatment of fractures of the hip and pelvis, perhaps the most popular and the most frequently used is the Whitman method which has served its purpose well and will probably be used in selected cases for a long time to come.

With the advent of the Jones traction splint, the author believes that a very definite step forward has been taken in the treatment of pelvic fractures, especially in the type most frequently encountered—the senile type.

Dr. Jones's splint makes use of the well leg as an aid to extension of the injured member. A fulcrum is thus produced, with the well leg as one arm of the lever and the injured leg as the other. The fulcrum might be taken as the pelvis from which leverage is applied to the injured member. Dr. Jones has informed the writer that he believes the actual pull on the traction arm to be about twenty pounds per three-fourths of an inch. However, in the first one-half of the distance on the traction arm, there is a pull of about fifteen to twenty pounds only, as allowance must be made for relaxation due to the cast and padding. The normal resistance of the patient's muscle pull is also considered in the traction force. The sacro-iliac ligaments receive some of the strain, which is again taken up in the symphysis.

TECHNIQUE

In most cases, the author has found morphine in conjunction with sodium amytal to be a sufficient anaesthetic. However, in cases where more relaxation is desired, spinal anaesthesia by the use of 100 milligrams of novocain may be used.

Sheet wadding is placed in even layers on both legs from the patient's knee to the toes. Next, harness-maker's felt, about one-quarter of an inch to three-eighths of an inch thick, is applied. In the case of the well leg, it is important to have the sole of the foot and the os calcis well padded, as the force here is upward. In the case of the injured leg, the dorsal surface must be heavily padded.

The writer is not afraid of using too much padding, as he believes that the best results are obtained in those cases in which there is free use of

FIG. 1

Application of felt boot.

For good leg: Sole of foot, heel, and outer aspect should be well padded.

For injured leg: Dorsum of foot and anterior surface of the leg should be well padded. Harness-maker's felt, one-fourth to three-eighths of an inch thick, is used.

FIG. 2

Application of splint.

Splint should be fitted to boot so that handle of splint is at right angles to horizontal plane of pelvis.

padding or felt. Four strips of felt are usually employed—one extending from the posterior surface of the knee and leg over the plantar surface of the foot, another over the anterior surface of the leg and the dorsum of the foot, and a strip on either side for the protection of the malleoli. It is important that the head of the fibula be well covered, as the peroneal nerve may be involved, especially in the well side.

Flexing the thigh on the pelvis and internal rotation with traction serve to bring the fractured ends into a more suitable position for further fixation by the splint.

In fractures of the pelvis, there should be manipulation through the vagina or rectum; at the same time traction should be applied by means of the splint.

The author uses approximately eight four-inch plaster bandages on each leg for the boot. In an hour this is sufficiently hard to incorporate the splint. Four to six four-inch bandages are used for this purpose.* Care must be taken to see that the traction barrel is in the exact center of the body and parallel with the long axis of the body. When this feature is overlooked, leverage is wrongly applied, and often poor results ensue.

After the cast hardens over the splint, the traction lever is turned until the patient complains of slight discomfort. This discomfort soon passes away with shrinkage of the plaster when sufficient felt has been used. A check-up x-ray is then made and, if further traction is needed, the traction barrel is moved further down. If, after full traction is induced, reduction is not satisfactory, the author does not hesitate to remove the casts and to reapply them.

REPORT OF CASES

In the cases studied, the chief object was to ascertain the percentages of bony union, shortening, and ankylosis. A series of letters was sent to the surgeons in attendance at the various cases and the results may be seen in Table I.

It is the author's belief that bony union in practically all cases is due to: first, proper reduction; and, second, the general well being of the patient during convalescence.

CONCLUSIONS

The Jones splint has the following advantages:

1. Mortality is greatly reduced, as may be seen in the author's series of cases in which five deaths occurred, giving a mortality rate of 12.5 per cent., which is much better than in his past experience with other procedures.

2. Hospital costs are made appreciably smaller. After the fracture has been reduced, the patient is easily cared for at home, unless complications make more constant care necessary.

* Since this article was written, the instrument has been improved so that it may be applied right over the plaster boot and no further plaster is used. This makes the splint still lighter.

TABLE I

ANALYSIS OF FORTY CASES OF FRACTURE OF THE PELVIS AND OF THE NECK OF THE FEMUR

Case No.	Name	Sex	Age (*Years*)	Time in Hospital (*Days*)	Complications	End Results
1	Mr. V. R. S.	M	42	161	None.	On crutches. Solid union.
2	Mrs. F. E.	F	82	21	Old hemiplegia.	Bony union. No shortening. No ankylosis.
3	Mr. G. R. B.	M	75	5	Myocarditis. Mitral regurgitation. Blood pressure 250/100.	Good bony union.
4	Mr. J. I.	M	71	48	None.	Good bony union. Shortening of one inch.
5	Mrs. W. D.	F	84	21	None.	Good bony union.
6	Mrs. E. P.	F	57	25	None.	Good bony union.
7	Mr. J. S.	M	84	17	None.	Good bony union.
8	Mr. M. M.	M	63	45	Mitral stenosis. Acidosis. Irregular heart.	Good functional result.
9	Mrs. F. H.	F	88	5	None.	Up in wheel chair after fourteen days. Good result.
10	Mrs. M. D.	F	63	75	None.	Good end result.
11	Miss K. L.	F	75	85	None.	Walking with cane at discharge.
12	Mrs. E. A.	F	83	10	None.	Bony union. No shortening.
13	Mrs. A. E.	F	86	60	None.	Bony union. Good result.
14	Mrs. A. R.	F	70	81	None.	Good bony union.
15	Mrs. M. S.	F	65	3	None.	Good result.
16	Mrs. C. H.	F	64	3	None.	Bony union.
17	Mrs. A. H.	F	76	72	None.	Up in wheel chair after forty-two days. Walking after sixty-one days.
18	Mrs. A. E.	F	52		Generalized cancer developed from old cancer of breast.	Death.
19	Mrs. V. H.	F	75	8	Postoperative cancer of the uterus *seven years ago.* This was a pathological fracture.	No follow-up obtainable.
20	Mrs. E. D.	F	66	7	None.	Walked with assistance after four months.

TABLE I (*Continued*)

ANALYSIS OF FORTY CASES OF FRACTURE OF THE PELVIS AND OF THE NECK OF THE FEMUR

Case No.	Name	Sex	Age (*Years*)	Time in Hospital (*Days*)	Complications	End Results
21	Mrs. F. A.	F	53	62	Wassermann reaction ++++.	Good bony union following antiluetic treatment. Shortening of one and one-half inch.
22	Mr. J. G.	M	83	43	Left hemiplegia. Lobar pneumonia.	No follow-up.
23	Mr. L. D. R.	M	56	7	None.	Good result.
24	Mrs. L. L.	F	53	35	Refracture. Too early weight-bearing.	Splint reapplied. End result satisfactory.
25	Mrs. E. W.	F	68	3	None.	Bony union.
26	Mr. L. R.	M	56	7	None.	Walking three and one-half months after fracture.
27	Mrs. M. K.	F	66	51	Partial paralysis of right side.	Death six weeks later, due to myocarditis.
28	Mrs. S. N.	F	72	20	None.	Good bony union.
29	Mrs. M. W.	F	78	35	Delirium. Extreme shock.	Shortening of one and one-half inches. Good bony union.
30	Mrs. B. B.	F	86	21	Cardiorenal.	No follow-up.
31	Mr. J. A. H.	M	82	5	Pneumonia.	Death.
32	Mrs. J. R.	F	85	21	None.	Bony union. No shortening. Abduction limited to 50 per cent.
33	Mrs. M. M.	F	50	74	Old mitral insufficiency.	Jones splint removed and Buck's extension applied because of shortening of one and one-half centimeters.
34	Mr. A. C.	M	40	11	Some numbness over peroneal nerve and muscles supplied by it.	Sent to San Francisco in splint. End result satisfactory.
35	Mr. J. E. K.	M	80	41	Old cerebral hemorrhage. Myocarditis. Auricular fibrillation.	Death. Autopsy showed atrophy of both kidneys and cystic degeneration.
36	Mrs. K. L.	F	35	55	None.	Good.
37	Mrs. A. M.	F	60	5	Cerebral embolus.	Death.
38	Mrs. S. T.	F	74	20	None.	Good bony union. No shortening
39	Miss R.	F	25	15	Fracture of transverse processes of three vertebrae.	Back at work as dietitian
40	Miss S. L.	F	23	10	Fracture of two vertebrae.	Back at work as nurse. Good result.

FIG. 3

A. A. Fractured pelvis. Before reduction.

FIG. 4

A. A. After reduction.

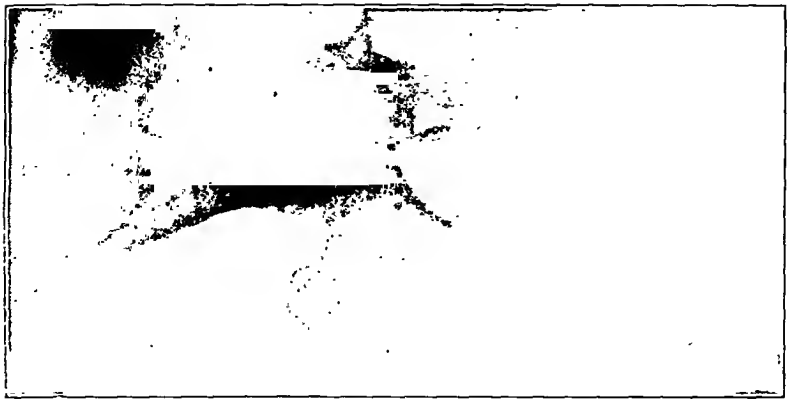

FIG. 6

A. H. After application of splint.

FIG. 5

A. H. Before application of splint.

3. Handling the patient for use of the bedpan or for a change of bed linen is simple, especially with the aid of the overhead frame by which the patient may raise himself.

4. Because of the ease in handling the patient, bed sores are rare. Since there is no plaster above the knees, there is, of course, no chance for urine or faeces to filter in between the skin and the cast and set up irritation.

5. The free motion permitted is important, especially in the treatment of the aged where hypostasis so frequently follows long convalescence in plaster casts.

6. The mental condition of the patient using the Jones splint has been found to be much better than that of the patient immobilized in a body cast such as the Whitman technique requires. When the Jones splint is used, the patient may be placed in a wheel chair and allowed in the sun the first week after the cast is applied.

7. The splint is easily applied by any general practitioner.

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